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THE MODEL OF POTENTIAL BIOMASS PRODUCTION OF RIPARIAN STANDS IN ODRA RIVER BASIN

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Abstract

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In Central Europe, there is a several centuries long tradition of the flood-protection regulation of watercourses by means of biological engineering measures. Various species of willows show ideal conditions for this way of use. From the point of view of economy, however, bank protection by willows is very expensive and the use of wicker is rather limited. Only the use of wood for energy purposes provides a chance to change this unfavourable situation. With the present cost of energies obtaining energy wood can at least partly cover costs for the maintenance of banks protected and reinforced by biological measures. Total adjustment of costs is not necessary because flood protection is partly covered from all-society sources. Efforts for the energy use of wicker obtained from biologically reinforced banks date back before the year 2000 when the economic stimulation to replace fossil fuels by woody biomass did not exist in the Czech Republic due to cost deformation of fossil fuels. Present (and quite certainly also future) costs of heat and electric energy make an intention to use wicker for energy purposes absolutely realistic. The production potential of natural stands of white willow was studied in communities developed due to primary succession. The biomass of stems, branches, annual rings and leaves was determined on the basis of samples taken destructively corresponding to the mean of particular diameter classes. Subsequently, the conversion of values of the biomass production was carried out per the area unit or per the watercourse length unit. The Odra river basin was selected as a model basin. Forest site survey and mapping were carried out there. On the basis of the survey suitable sections of watercourses were determined fulfilling ecological requirements of white willow. By means of their quantification, the calculation was carried out of the energy potential of riparian stands in the model catchment area. The study results in assessing the realistic potential of wicker used for energy purposes which can be obtained without any demand on forest or agricultural land.

Key words: Odra river basin, forest site mapping, *Salix alba* L., potential biomass production

Introduction

In Czech lands, torrent training develops traditionally using close-to-nature methods of bank protection since the beginning of the 19th century. One of the methods is living riprap when streambanks are stabilized by stones of local origin and cuttings of shrubby willows are planted into gaps between stones. After flushing, these willows hide visually contours of a technical work because torrent training is the technical work beyond dispute. An advantage of the combination of a technical and biological protection of banks consists in the stabilization of streambanks by roots of willows and, above all, during the increased water level shrubby willows "lie down" due to the water pressure to the streambed and prevent (by their roots and branches) the erosion of stones reinforcing the river bank. At this bio-technical treatment, there is no need of massive protection using concrete as it would be necessary by reason of hydraulic resistance at purely technical measures. Thus, the bio-technical protection of torrents represents also a unique ecotone and line element of ecological stability. It was demonstrated in recent decades when biological stabilization of banks restricted effectively the distribution of invasive *Reynoutria.* However, a necessity to maintain stands of shrubby willows is a disadvantage of the bio-technical protection of torrents. These stands have to be regularly cut down in an interval of max. 3 years not to overgrow and to keep their decumbent character at higher levels of water. If shrubby willows overgrow to an arborescent form they "extend" for light above the watercourse, cause ruptures of banks, break and close the watercourse flow profile. Because maintaining the flow profile is a flood control priority managers of watercourses abandon the requirement of bio-technical measures due to work difficulty and costs of their maintenance and replace them by technical measures, which are relatively maintenance-free but effect as an inorganic element in the natural environment.

Objectives of the paper

The main objective of the paper was to demonstrate possibilities of using osiers obtained at the maintenance of the bio-technical stabilization of torrents for energy purposes. To attain this objective following partial objectives were formulated:

- to test through the method of geobiocoenological mapping the biological acceptability of using willows for the bio-technical stabilization of banks of torrents in the Odra river basin,
- on the basis of geobiocoenological mapping and using production analyses from another region of the Czech Republic to quantify the production potential of the bio-technical stabilization of stream banks,
- to assess possibilities of using material obtained from the maintenance of the bio-technical stabilization of banks as energy wood,
- to formulate recommendations for the basin area manager,
- to formulate other objectives of basic and application research.

Material and methods

Study area

The preparation of geobiocoenological maps of the riparian zone of watercourses was carried out along all important watercourses in the Odra river basin (in total 75 watercourses) administered by the Povodí Odry Co. The Odra river basin occupies an area of 10 288 km^2 (Vlček et al., 1984) in the Czech Republic. The total length of mapped parts of watercourses amounts to 1 256.6 km (2 507.2 km taken account of both banks) (Buček et al., 1999, 2000, 2001). For potential biomass evaluation, the only suitable parts of watercourses for plantation of white willow were selected (2nd to 3rd vegetation tire).

Geobiocoenological mapping of the Odra river basin and the analysis of results

Geobiocoenological mapping is a reconstruction mapping depicting in principle segments of potential natural vegetation or its geobiocoenoses, namely on the level of geobiocoene type groups. Groups of geobiocoene types are associated types of geobiocoenes with similar permanent ecological conditions. Types of geobiocoenoses are associated into groups on the basis of phytocoenological similarity of natural forest biocoenoses in the stage of maturity. Groups of geobiocoene types occur within so much homogenous ecological conditions (climatic, trophic and hydric) that they are characterized by a certain species composition and spatial structure of biocoenoses, productivity and dynamics of their development. Thus, it is possible to relate them to a certain functional potential and optimum possibility of using corresponding to natural conditions (Zlatník, 1973, 1976a).

The aim of field mapping was to differentiate groups of geobiocoene types along watercourses as frameworks of permanent ecological conditions. The mapping was carried out in a "riparian zone", which was specified as a double-sided belt along a watercourse including the river bed and adjacent plots in the floodplain and on neighbouring slopes usually up to 50 m from the river bed margin.

The list of mapped groups of geobiocoene types is as follows:

a) moister types in wide river alluviums

Alni glutinosae-saliceta = AlS / (2)3-3BC5b(a) / in depressions with waterlogged gleys in wide floodplains

Alneta = Al / (2)3-3BC5ab / in depressions with waterlogged gleys in wide floodplains along watercourses

Saliceta albae = Sa / (2)3B-C5a / on gravel-sand deposits in a stream bed

Querci roboris-fraxineta = QFr / (2)3-3BC-C(4)5a / on heavy-textured soils (fluvisols) in wide floodplains with groundwater table up to 150 cm

b) drier types in wide river alluviums

Ulmi-fraxineta populi = UFrp / (2)3-3BC-C(4)5a / on arenaceous Fluvisols in wide floodplains with groundwater table up to 150 cm

Ulmi-fraxineta carpini = UFrc / 3BC-C(3)-4 / on Fluvisols in wide floodplains with groundwater table below 150 cm

c) moister types in narrow brook alluviums

Saliceta fragilis = Sf / (2)3-3B-C5a, 4-5B-C5a / on gravel-sand deposits in a stream bed

Fraxini-alneta = FrAl / 3BC-C(4)5a, 4-5BC-C(4)5a / on Fluvisols in floodplains in bottoms of valleys of uplands and highlands with groundwater table usually up to 1 (1.5) m

d) drier types in narrow brook alluviums

Fraxini-alneta aceris = FrAlac / 3BC(4)5a, / 4-5BC4(5a) / on elevated parts of floodplains in bottoms of valleys of uplands and highlands with groundwater table below 150 cm

Contact GTG = GTG outside floodplains (in case they intervene into a riparian zone).

Explanatory notes:

vegetation tires: 3. oak/beech, 4. beech/oak, 5. fir/beech,
trophic series and inter-series: B – mesotrophic, BC – mesotrophic-nitrophilous, C – nitrophilous,
hydric series: 3 – normal, 4 – waterlogged, 5a – wet, flowing water, 5b – wet, stagnant water.

In the course of field surveys, groups of geobiocoene types (GTG) were mapped as frameworks of permanent ecological conditions (Zlatník, 1976b; Buček, Lacina, 1999). Segments of the riparian zone landscape were included in GTG on the basis of bioindication by vegetation (particularly in more natural parts) and on the basis of differences in soil conditions particularly the groundwater table and soil texture.

In the GIS TopoL environment, lengths of particular segments were added (according to river km) occupied by the relevant group of geobiocoene types within vegetation tires.

The natural model of productivity

As input data for evaluating the production potential of the Odra river basin results were used of monitoring the succession of white willow communities in the region of Nové Mlýny reservoirs. The Nové Mlýny reservoirs are situated on the confluence of the Dyje, Svratka and Jihlava rivers about 40 km south of Brno in the Czech Republic. Spontaneous succession started in 1996 when the reservoir level was decreased by 85 cm in connection with the construction of a biocorridor through the Nové Mlýny middle reservoir. On several tens of hectares of exposed banks and deposits, the rare natural succession of communities of a "soft-wooded" floodplain started. Since 1996, the dynamics of succession processes was monitored in 40 research plots (Buček et al., 2001). In the majority of plots of an area of 25 to 1000 m^2, population density, tree height and girth at breast height (gbh) were monitored. In selected plots, production analysis was carried out with an objective to determine the dry weight of above-ground biomass in stems, branches, annual shoots and leaves (Newbould, 1967, modified) and obtained results were interpolated on unit of area. Quantification of woody biomass utilizable for energy purposes will be adopted from the done production analysis (Buček et al., 2004). The content of energy in the dry matter (DM) of these organs was also determined. The calorific value was tested in the laboratory by Bomb Calorimeter PARR 1281 (f. PARR, USA). Research plots were mostly situated into closed stands, however, some plots also into relatively narrow riparian stands. During the research, 19 sample trees were analysed using a destructive method and gbh and height were measured in more than 2000 trees. Allometric relationships were used to calculate quantities, which were not measured in some plots. Plots were also classified according to the kind of a substrate and according to the distance from the bank line:

1) narrow riparian stands on loamy-stone dam bases,
2) narrow riparian stands on clayey sediments,
3) wide closed stands on clayey sediments:
   (a) at a distance of 0–10 m from the bank line,
   (b) at a distance of 10–25 m from the bank line,
   (c) at a distance of 25–40 m from the bank line.

From determined data, correlations were calculated between the age of a succession stage and growth or production characteristics (tree height, DBH, stem volume per hectare and biomass production per hectare), which were subsequently used to model the potential production of the watershed biomass.

Results

Results of Odra river basin geobiocoenological mapping

With respect to the occurrence of white willow in natural and close-to-nature geobiocoenoses up to the 3rd vegetation zone inclusive, the quantification of sites was carried out for transition from the 2nd to the 3rd vegetation zone (marked (2)3. vs) and for the 3rd vegetation zone. For the purpose of comparisons with sites where studies of the biomass growth were carried out groups of geobiocoene types were aggregated into four groups (a–d, see methods above). 1 765.38 km from total 2 507.2 km of bank sides length were classified as suitable parts of watercourses for plantation of white willow (Table 1).

T a b l e 1. Quantification of sites (summary) in km of watercourses.

(in km)	Moister biotops	Drier biotops	Total
Wide river alluvium (2)3.vz	30.21	54.177	87.408
Wide river alluvium 3.vz	241.853	479.793	745.831
Narrow brook alluvium	334.245	564.474	932.144
Total	606.308	1 098.44	1 765.38

The potential condition of vegetation informs on possibilities to create biomass from the viewpoint of the complex of factors of the abiotic environment, particularly climatic conditions, soil moisture regime and nutrient availability.

The model of biomass production for narrow brook alluviums

The data from monitoring plots of narrow riparian stands on loamy-stone dam bases were used for biomass production model.

The correlation between growth characteristics (tree height, DBH, stem volume per hectare and biomass production per hectare) and age of succession stage were calculated (Figs 1–4).

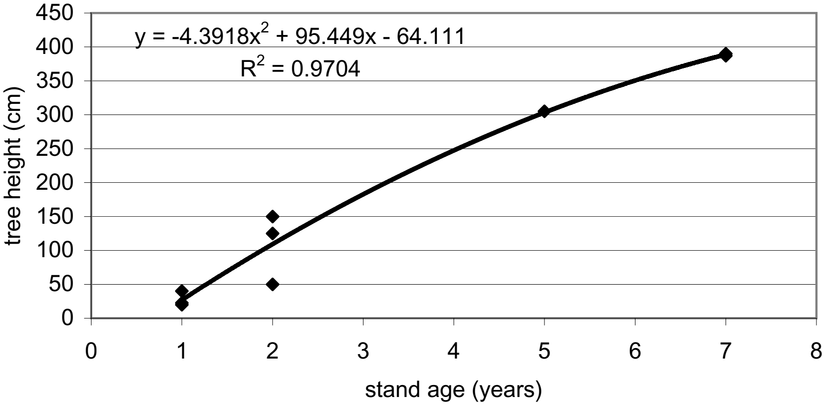

Fig. 1. The correlation between mean tree height and stand age on the research plots with narrow riparian stands on loamy-stone dam basis.

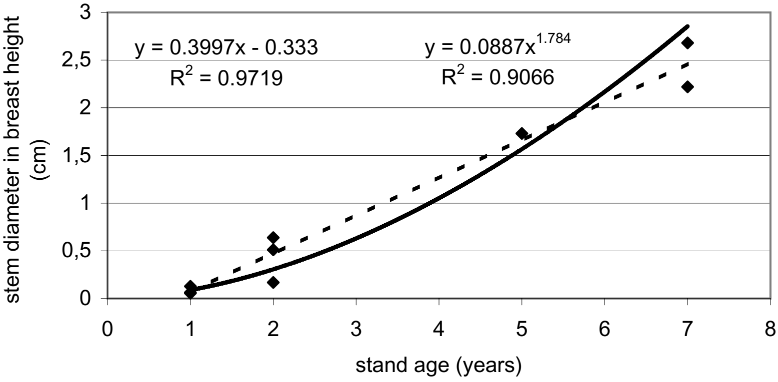

Fig. 2. The correlation between mean DBH and stand age on the research plots with narrow riparian stands on loamy-stone dam basis.

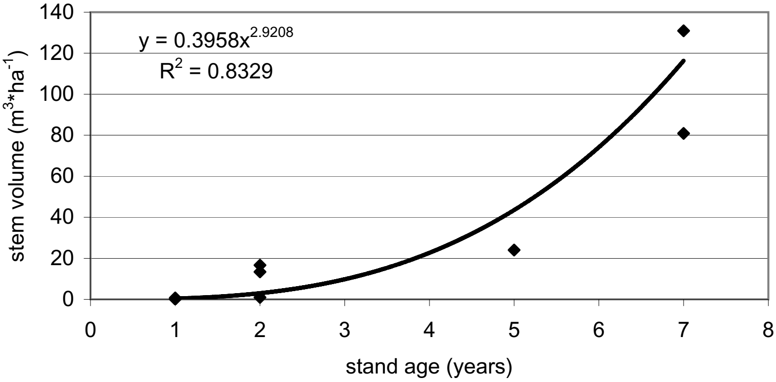

Fig. 3. The correlation between stem volume and stand age on the research plots with narrow riparian stands on loamy-stone dam basis.

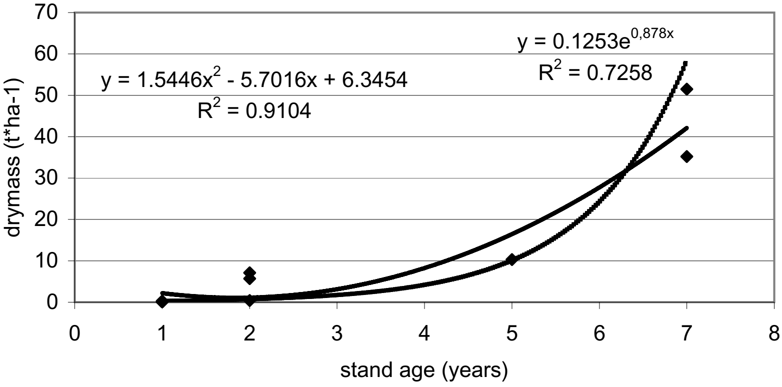

Fig. 4. The correlation between drymass and stand age on the research plots with narrow riparian stands on loamy-stone dam basis.

The model of biomass production for different width of riparian stands (1 to 5 m) on narrow brook alluviums is demonstrated in Table 2.

Table 2. Biomass production for different width of riparian stands (1 to 5 m) on narrow brook alluviums (in tons).

Age (years)/ width of stand (m)	1	2	3	4	5
1	203,990393	407,9807859	611,9711789	815,9615718	1019,951965
2	104,4560566	208,9121133	313,3681699	417,8242266	522,2802832
3	292,8796448	585,7592896	878,6389344	1171,518579	1464,398224
4	769,2611574	1538,522315	2307,783472	3077,04463	3846,305787
5	1533,600595	3067,201189	4600,801784	6134,402378	7668,002973
6	2585,897956	5171,795912	7757,693868	10343,59182	12929,48978
7	3926,153242	7852,306484	11778,45973	15704,61297	19630,76621

The model of biomass production for narrow riparian stands on wide river alluviums

The data from monitoring plots of narrow riparian stands on clayey sediments were used for biomass production model.

The correlation between growth characteristics (tree height, DBH, stem volume per hectare and biomass production per hectare) and age of succession stage were calculated (Figs 5–8).

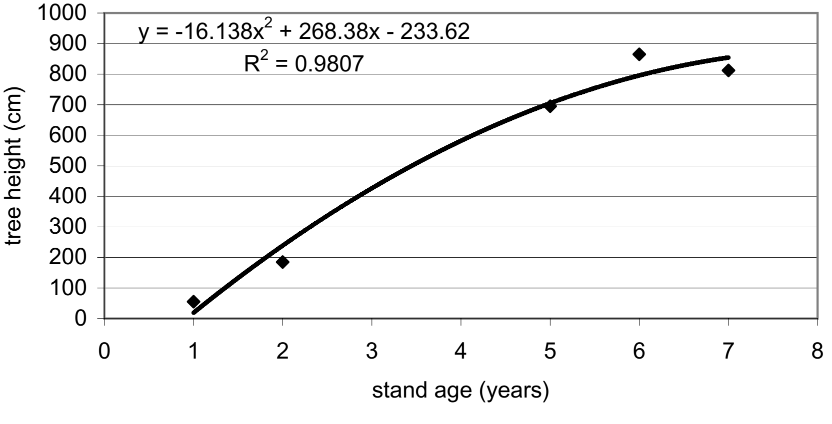

Fig. 5. The correlation between mean tree height and stand age on the research plots with narrow riparian stands on clayey sediments near the bank line.

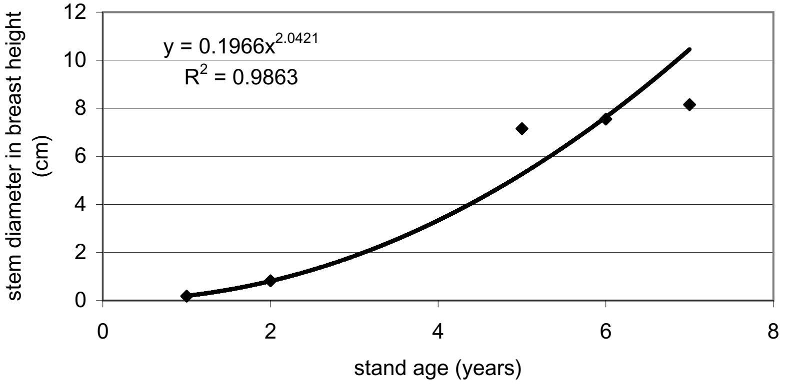

Fig. 6. The correlation between mean DBH and stand age on the research plots with narrow riparian stands on clayey sediments near the bank line.

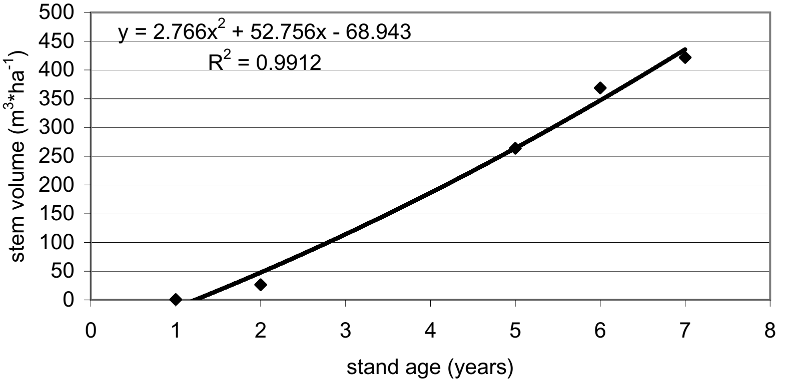

Fig. 7. The correlation between stem volume and stand age on the research plots with narrow riparian stands on clayey sediments near the bank line.

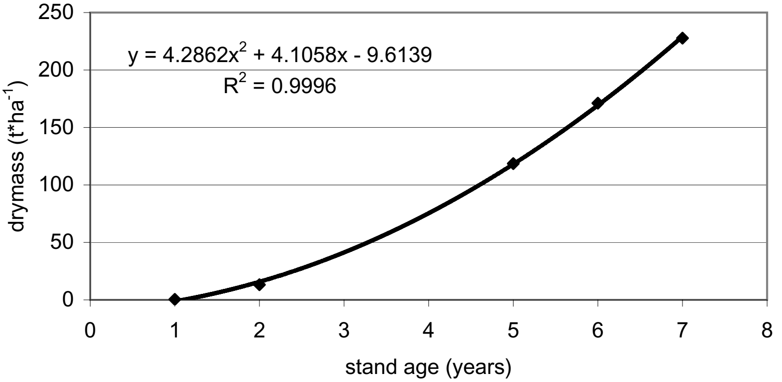

Fig. 8. The correlation between drymass and stand age on the research plots with narrow riparian stands on clayey sediments near the bank line.

The model of biomass production for different width of narrow riparian stands (1 to 5 m) on wide river alluviums is demonstrated in Table 3.

T a b l e 3. Biomass production for different width of narrow riparian stands (1 to 5 m) on wide river alluviums (in tons).

Age (years)/ width of stand (m)	1	2	3	4	5
1	-	-	-	-	-
2	1311,726496	2623,452992	3935,179487	5246,905983	6558,632479
3	3439,552265	6879,104531	10318,6568	13758,20906	17197,76133
4	6281,663835	12563,32767	18844,99151	25126,65534	31408,31918
5	9838,061205	19676,12241	29514,18362	39352,24482	49190,30603
6	14108,74438	28217,48875	42326,23313	56434,9775	70543,72188
7	19093,71335	38187,42669	57281,14004	76374,85339	95468,56673

The model of biomass production for closed stands on wide river alluviums

The data from monitoring plots of wide closed stands on clayey sediments were used for biomass production model.

The correlation between growth characteristics (tree height, DBH, stem volume per hectare and biomass production per hectare) and age of succession stage were calculated (Figs 9–20).

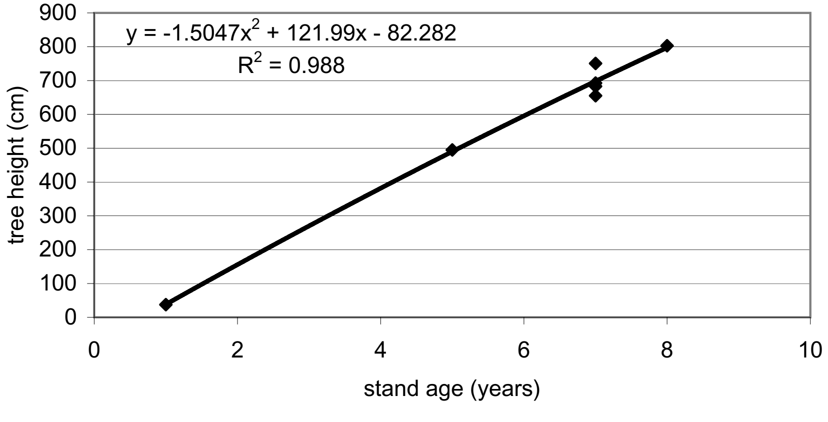

Fig. 9. The correlation between mean tree height and stand age in the research plots with closed wide riparian stands on clayey sediments 0–10 m distant from the bank line.

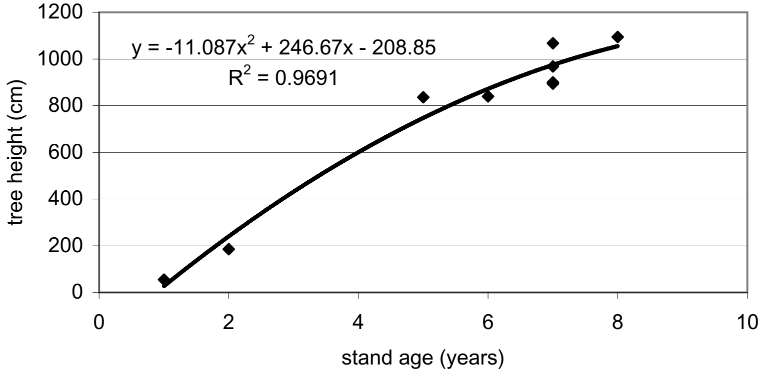

Fig. 10. The correlation between mean tree height and stand age in the research plots with closed wide riparian stands on clayey sediments 10–25 m distant from the bank line.

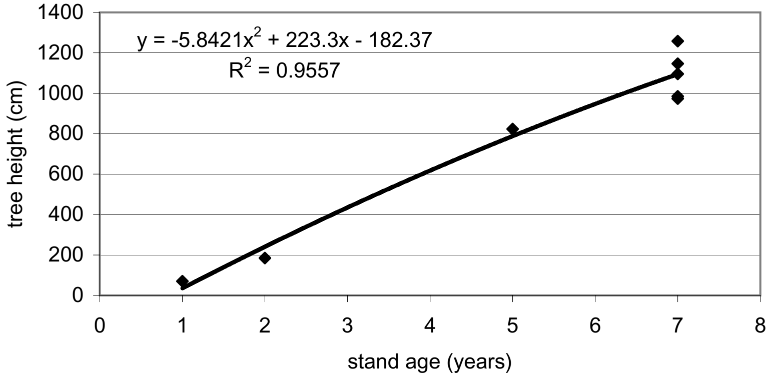

Fig. 11. The correlation between mean tree height and stand age in the research plots with closed wide riparian stands on clayey sediments 25–40 m distant from the bank line.

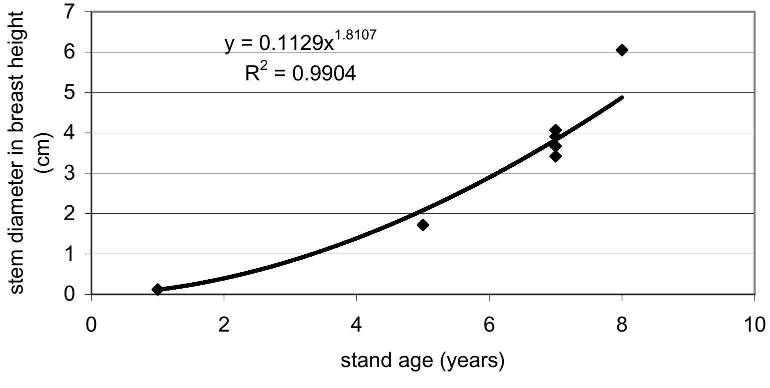

Fig. 12. The correlation between mean tree diameter and stand age in the research plots with closed wide riparian stands on clayey sediments 0–10 m distant from the bank line.

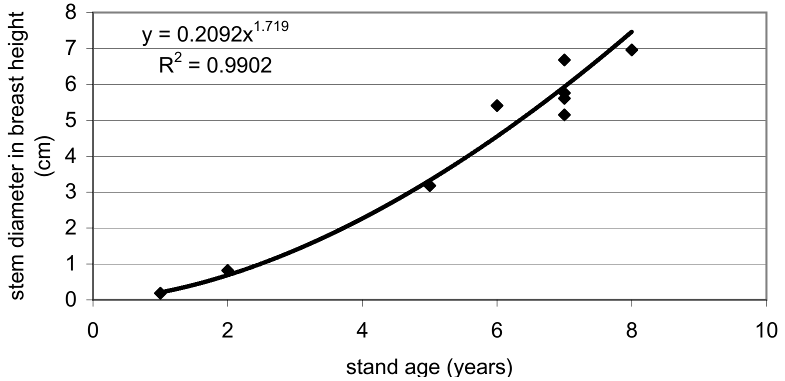

Fig. 13. The correlation between mean tree diameter and stand age in the research plots with closed wide riparian stands on clayey sediments 10–25 m distant from the bank line.

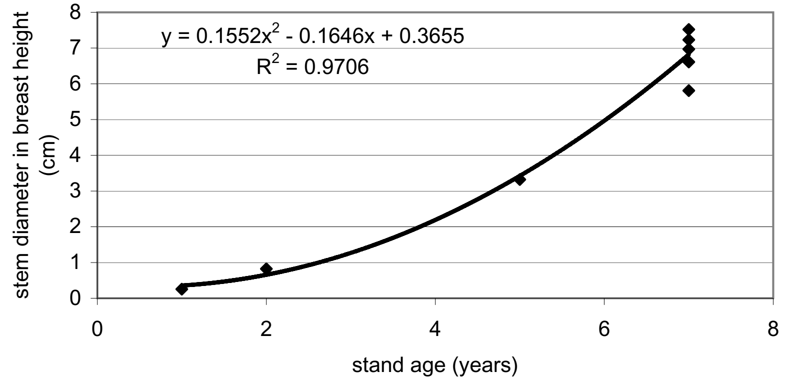

Fig. 14. The correlation between mean tree diameter and stand age in the research plots with closed wide riparian stands on clayey sediments 25–40 m distant from the bank line.

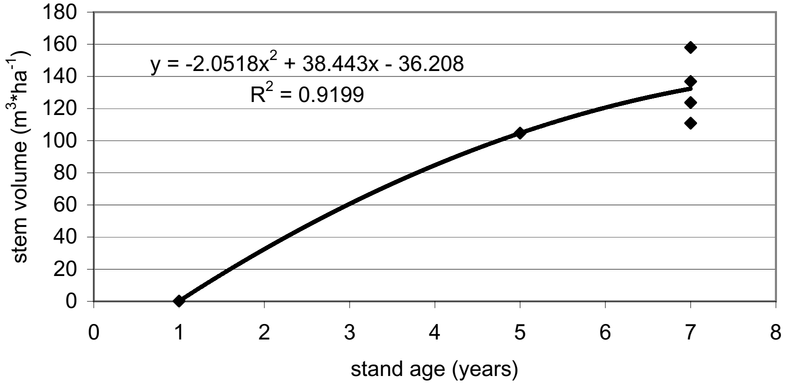

Fig. 15. The correlation between stem volume and stand age in the research plots with closed wide riparian stands on clayey sediments 0–10 m distant from the bank line.

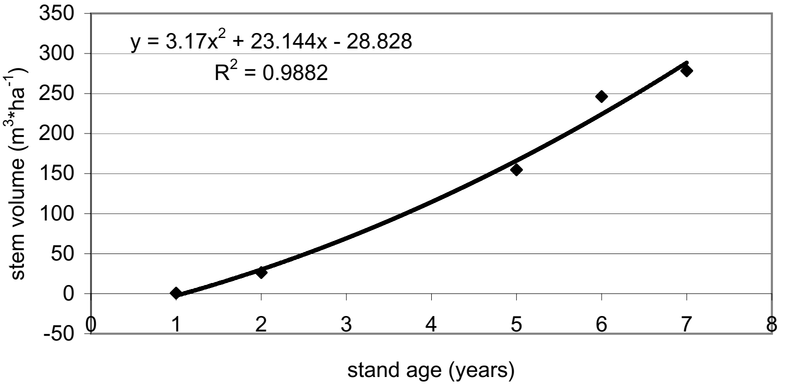

Fig. 16. The correlation between stem volume and stand age in the research plots with closed wide riparian stands on clayey sediments 10–25 m distant from the bank line.

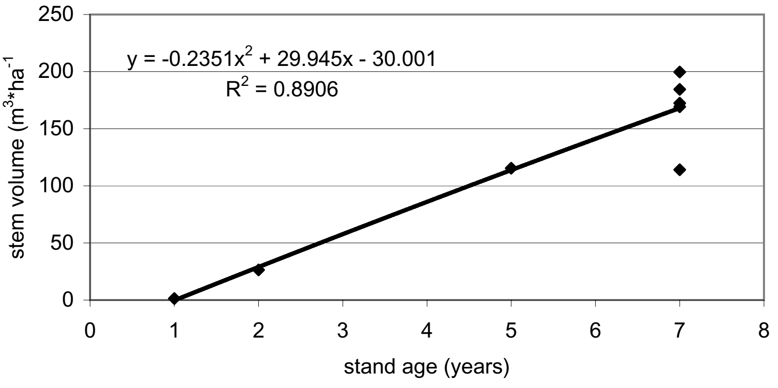

Fig. 17. The correlation between stem volume and stand age in the research plots with closed wide riparian stands on clayey sediments 25–40 m distant from the bank line.

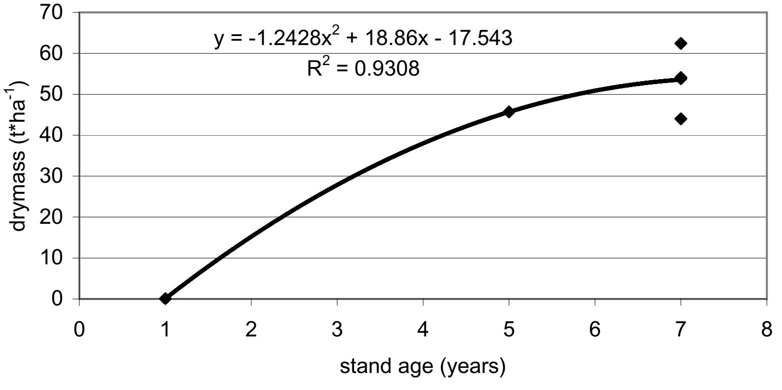

Fig. 18. The correlation between DM and stand age in the research plots with closed wide riparian stands on clayey sediments 0–10 m distant from the bank line.

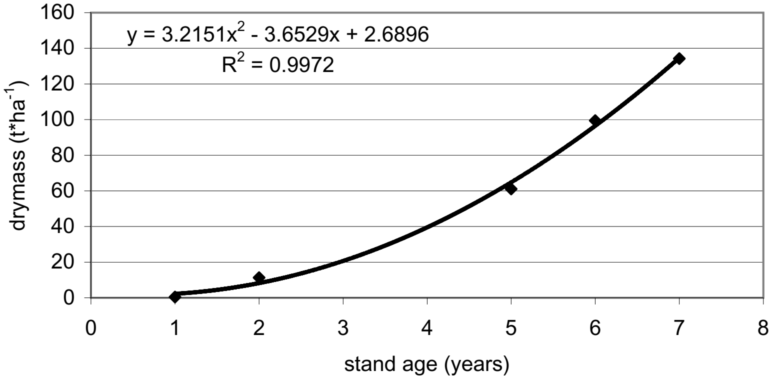

Fig. 19. The correlation between DM and stand age in the research plots with closed wide riparian stands on clayey sediments 10–25 m distant from the bank line.

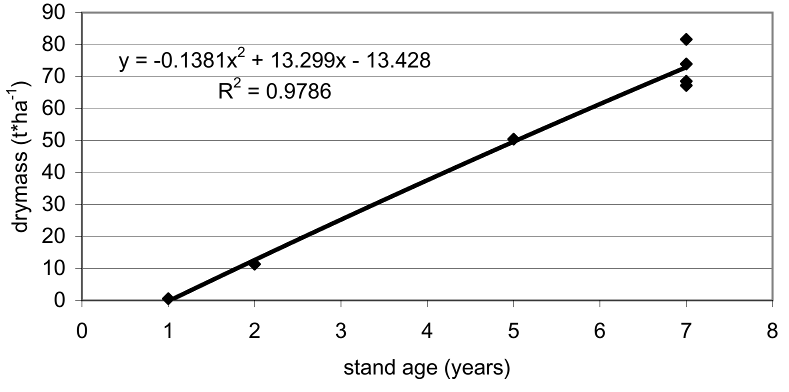

Fig. 20. The correlation between DM and stand age in the research plots with closed wide riparian stands on clayey sediments 25–40 m distant from the bank line.

The model of biomass production for different width of closed riparian stands (1 to 40 m) on wide river alluviums is demonstrated in Table 4.

T a b l e 4. Biomass production for different width of closed riparian stands (1 to 40 m) on wide river alluiviums (in tons).

Age (years)/ width of stand (m)	1	2	3	4	5	10
1	6,18263338	12,36526676	18,54790014	24,73053352	30,9131669	61,8263338
2	1267,006559	2534,013117	3801,019676	5068,026234	6335,032793	12670,06559
3	2320,720598	4641,441196	6962,161794	9282,882392	11603,60299	23207,20598
4	3167,324752	6334,649503	9501,974255	12669,29901	15836,62376	31673,24752
5	1,823798892	7613,638039	11420,45706	15227,27608	19034,0951	38068,19019
6	4239,203401	8478,406802	12717,6102	16956,8136	21196,01701	42392,03401
7	4464,477897	8928,955794	13393,43369	17857,91159	22322,38949	44644,77897
Age (years)/ width of stand (m)	15	20	25	30	35	40
1	999,9701239	1938,113914	2876,257704	2764,978636	2653,699567	2542,420499
2	16104,76007	19539,45455	22974,14903	28230,88724	33487,62544	38744,36364
3	31817,39786	40427,58975	49037,78163	59547,4668	70057,15197	80566,83713
4	48137,88351	64602,5195	81067,15549	96714,71732	112362,2792	128009,841
5	65066,217	92064,24381	119062,2706	139732,6388	160403,007	181073,3752
6	82602,39835	122812,7627	163023,127	188601,2313	214179,3355	239757,4397
7	100746,4275	156848,0761	212949,7247	243320,4947	273691,2646	304062,0346

The total estimation of potential biomass production for Odra river basin

The total potential biomass production was calculated as a sum of above-mentioned models, for narrow riparian stands (Table 5) and for closed wide stands (Table 6).

T a b l e 5. Total potential biomass production for narrow riparian stands (in tons).

Age (years)/ width of stand (m)	1	2	3	4	5
1	102,1769196	204,3538391	306,5307587	408,7076782	510,8845978
2	1416,182552	2832,365105	4248,547657	5664,73021	7080,912762
3	3732,43191	7464,86382	11197,29573	14929,72764	18662,15955
4	7050,924993	14101,84999	21152,77498	28203,69997	35254,62496
5	11371,6618	22743,3236	34114,9854	45486,6472	56858,309
6	16694,64233	33389,28466	50083,927	66778,56933	83473,21166
7	23019,86659	46039,73318	69059,59977	92079,46636	115099,3329

T a b l e 6. Total potential biomass production for closed wide stands (in tons).

Age (years)/ width of stand (m)	1	2	3	4	5	10
1	210,1730263	420,3460527	630,519079	840,6921054	1050,865132	1081,778299
2	1371,462615	2742,925231	4114,387846	5485,850461	6857,313076	13192,34587
3	2613,600243	5227,200486	7840,800728	10454,40097	13068,00121	24671,6042
4	3936,585909	7873,171818	11809,75773	15746,34364	19682,92955	35519,5533
5	5340,419614	10680,83923	16021,25884	21361,67846	26702,09807	45736,19317
6	6825,101357	13650,20271	20475,30407	27300,40543	34125,50679	55321,52379
7	8390,631139	16781,26228	25171,89342	33562,52456	41953,1557	64275,54518
Age (years)/ width of stand (m)	15	20	25	30	35	40
1	2081,748423	3019,892213	3958,036003	6723,014638	6611,73557	6500,456501
2	29297,10594	32731,80042	36166,4949	64397,38214	69654,12034	74910,85854
3	56489,00207	65099,19395	73709,38583	133256,8526	143766,5378	154276,223
4	83657,43681	100122,0728	116586,7088	213301,4261	228948,9879	244596,5498
5	110802,4102	137800,437	164798,4638	304531,1026	325201,4708	345871,839
6	137923,9221	178134,2865	218344,6508	406945,8821	432523,9863	458102,0905
7	165021,9727	221123,6213	277225,2699	520545,7645	550916,5345	581287,3045

Total energy content in biomass was estimated as a multiple of total biomass production and mean weighted average of heating capacity of willow wood (17.7205 $MJ*kg^{-1}$), for narrow riparian stands (Table 7) and for closed wide stands (Table 8).

T a b l e 7. Total energy content in biomass for narrow riparian stands (in KJ).

Age (years)/ width of stand (m)	1	2	3	4	5
1	1810626,103	3621252,206	5431878,309	7242504,412	9053130,514
2	25095462,92	50190925,84	75286388,76	100381851,7	125477314,6
3	66140559,66	132281119,3	198421679	264562238,6	330702798,3
4	124945916,3	249891832,7	374837749	499783665,3	624729581,7
5	201511532,9	403023065,9	604534598,8	806046131,7	1007557665
6	295837409,4	591674818,9	887512228,3	1183349638	1479187047
7	407923545,9	815847091,8	1223770638	1631694184	2039617729

T a b l e 8. Total energy content in biomass for closed wide stands (in KJ).

Age (years)/ width of stand (m)	1	2	3	4	5	10
1	3724371,113	7448742,227	11173113,34	14897484,45	18621855,57	19169652,34
2	24303003,27	48606006,55	72909009,82	97212013,09	121515016,4	233774965
3	46314303,1	92628606,21	138942909,3	185257212,4	231571515,5	437193162,3
4	69758270,6	139516541,2	209274811,8	279033082,4	348791353	629424244,3
5	94634905,77	189269811,5	283904717,3	378539623,1	473174528,8	810468211
6	120944208,6	241888417,2	362832625,8	483776834,4	604721043	980325062,4
7	148686179,1	297372358,2	446058537,3	594744716,4	743430895,5	1138994798
Age (years)/ width of stand (m)	15	20	25	30	35	40
1	36889622,92	53513999,95	70138376,99	119135180,9	117163260,2	115191339,4
2	519159365,8	580023869,3	640888372,9	1141153810	1234305839	1327457869
3	1001013361	1153590266	1306167172	2361378057	2547614933	2733851809
4	1482451609	1774213191	2065974773	3779807921	4057090541	4334373160
5	1963474109	2441892644	2920311178	5396443404	5762732663	6129021922
6	2444080862	3156628624	3869176385	7211284503	7664541299	8117798095
7	2924271868	3918421131	4912570395	9224331221	9762516450	10300701679

Discussion

Assessing of biomass production

The initial stages of white willow communities established in primary succession (Matic et al., 1999; Bergmann, 1999) belong to high productive ecosystems (Buček et al., 2004); this is given by highly fertile alluvial soils, sufficient moisture and long vegetation period. White willow is a typical pioneer species of the riparian forest ecosystem, R-strategist (Grimme, 1979) with a fast growth in juvenility.

The high light demands support the height increment (Kajba et al., 1999), the average annual height increment on the research plots exceeds 1 m and by highest specimens approachs 2 m. Study of Vinay-Kumar et al. (1998) shows the height of three years old white willow over 2 m. The hydrological conditions influence significantly the rate of growth too (Agafonov, 1995). White willow belongs to short rotation species with significant volume increment (Klasnja, Kopitovic, 1999). The reserve of dendromass is 200 to 300 m^3 per hectare for 25 to 30 years old white willow stand and 400 m^3 per hectare for 40 years old stand in Don and Volga rivers alluviums (Klimo, Hager, 2000). The average annual increment of 7 years old stand on the our most productive research plot reachs 50 m^3 per hectare and the increment in 2003 reached even 105 m^3 per hectare. Hager et al. (1999) inform the stands of poplar hybrids in the Austrian alluvium of the Danube to exhibit an average annual increment for stand age of 50 years ranging from 8.0 to 35.4 $m^3*ha^{-1}*a^{-1}$.

The community of white willow in the locality produced 45–140 t DM per hectare, which was on average 75 t (Maděra, Kovářová, 2004). The production of DM (without leaves) per hectare per year is 16 t, including leaves 16.5 t. This value is very favourable exceeding the majority of species which are grown for energy purposes in Central Europe. The values exceed approximately ten times the data measured by Bungart et al. (2000) in the region of Lusatia, Germany for 3–4-year old stands of willows and poplars in mining areas. Kajba et al. (2004) mention the overall mean DM production of all the investigated clones was 6.5 tons per hectare, the greatest production was exhibited by clones ‚B44‘, ‚V093‘ and ‚V052‘ (10.2, 9.2 and 9.1 $t*ha^{-1}$, respectively).

Klasnja, Kopitovic (1997) mention the nominal wood density averaged about 340 $kg*m^{-3}$, with some differences between the clones and cellulose content was somewhat lower, and the contents of lignin and extractives were somewhat higher compared with poplar (*Populus* spp.) wood. Volume weight of willow is 271.128 $kg*m^{-3}$ absolute DM (Bozděch, Černák 1994). The calorific value of willow wood moves from 16 to 22 $MJ*kg^{-1}$ (Klasnja et al., 2002), compared with coal 27 MJ*kg-1 (National Association of Forest Industries. 2006 –http://www.nafi.com.au/bioenergy_factsheets/WWFS15.pdf). Height of calorific value depends on the portion of bark. The calorific value determined in the laboratory at production analyses differs according to the specific part of a plant. Annual shoots contain the higher content of bark (showing also higher calorific value than stemwood with respect to the higher content of volatile oils). Because the proportion of stemwood and the proportion of wood in annual shoots differ according to the age or diameter of willow trees the converted calorific value per the unit of wood volume is also different. Klasnja et al. (2002) refer the calorific values move from 16 169 $kJ*kg^{-1}$ (14-year old) to 22 572 $kJ*kg^{-1}$ for (2-year old).

The riparian stands in Odra river basin could produce, according to our models, from 3724.4 GJ (1 m wide stands in first year) to 10300701.7 GJ (40 m wide stands in seven years) energy contained in biomass. It means, the maximal potential riparian stands performance could reach 46.7 MW.

Assessing the possibility of the rationalization of maintenence of the bio-technical stabilization of banks

It is evident, that the potential biomass production of the Odra river basin is very high. The real biomass production will be lower due to technological reasons. Though we believe, that the riparian stands planting for bioenergetic purposes is absolutely realistic.

In the Czech Republic, there are no other available means of mechanization for harvesting shrubby willows on narrow strips (5 m) and on slopes adjacent to the water level than brush-cutters. The maintenance of this type of stabilization by cutting off willows has to be carried out in time because otherwise willows lose their flexibility, which is necessary in case of possible flood flows. The stump diameter of 5 cm can be considered to be a limiting diameter when willow is able at all to bend due to the effect of flowing water. Because standard brush-cutters (power category "profi") can be used for cutting stems up to a diameter of 6 cm by a single application and stems of greater diameter have to be cut "in two parts", the stage of a stand at the stump diameter 6 cm is the ultimate one when the cutting has to be carried out. Measurements carried out at the production analysis show that from the viewpoint of technical feasibility the utmost interval could be four-year. However, it holds only from the viewpoint of the willow diameter attained, which can be used only in wide watercourses, water reservoirs and plantations of energy willows. In narrow watercourses, where the closure of a flow profile threatens the stand height is a decisive factor for timely cutting the willow stems. Thus, growth conditions and locality will decide more on the time of cutting off than age. Thus, on the ground of maintaining ideal flow conditions it is desirable (according to the results of measurements within a production analysis) to cut off willows in the bio-technical stabilization every 2 years. Komlenovic et al. (1996) concluded that for short rotations of maximum 5 years, the number of sprouts per hectare should range between 20 000 and 25 000. For the purpose of greater productivity, after the first rotation, shoots should be reduced to one or two per stump. It has been also proved by practical experience in the Odra river basin.

The aim of cutting off willows is not their mere disposal but such cutting, which creates ideal conditions for a coppice system. Thus, cutting off willows should be always carried out after the perfect lignification of shoots after the growing season. From mid-December to April the risk of fungi infection decreases. The additional vegetable matter (leaves) in the chip will tend to degrade the quality of the fuel and therefore winter is the most suitable period for cutting off (http://www.ruralgeneration.com/Willow%20as%20wood%20fuel.doc). The cut has to be smooth for the bark on stumps not to be torn (risk of mildews, fungi and insect attack). It can be achieved only when using circular saw blades with special teeth (Cobra Blade). Cutting off using brush cutters does not make possible to lead a cut less than 10 cm above the soil surface on stony ground. Thus, regeneration from stumps is sabre-shaped, which virtually forbids to use harvested withes for wicker-work.

The transport of osier to an accompanying road can be carried out only manually. If the wicker will be deposited outside the flooded area it can be kept there till its drying. It cannot remain in the flooded area not to be flushed away to a watercourse and thus create an obstacle in case of a flood wave. In such cases, it will be necessary to transport wicker up to the place of processing. It is not economical to move wood chips over long distances in the way that oil and gas are moved. Because of the low bulk density (approximately 200 $kg*m^{-3}$) of willow chip it is desirable to use short rotation willow coppice close to where it is grown. It is recommended that boiler/plant is within 16 km radius of willow production outlet (http://www.ruralgeneration.com/Willow%20as%20wood%20fuel.doc).

It is possible to carry out chipping only after drying because osier is so flexible under conditions of natural moisture that fractions of extra-large dimensions go through standard chippers.

Bio-technical stabilization of banks as a source of energy wood and improvement of biocorridor function of rivers

The Czech Republic falls behind the majority of EU countries in the use of wood as the source of energy. However, demand for energy wood steadily increases and its cheap sources (bark, sawdust, saw-mill residues) have been already depleted. Thus, interest is concentrated on more expensive sources (logging residues, wood from cleaning and thinning operations). Although the present situation in the CR can be termed as the period of market formation with energy wood demand for the source is a reality.

Interesting is certainly a possibility of using the initial stages of white willow communities for the implementation of energy stands on flood-control polders, making use of their high starting biomass increment rate, high vitality, very good resistance to long-term flooding. At the same time they fulfil a considerable ecostabilizing and corridors functions in the riverine landscape as a native type of plant communities.

Conclusion

Based on results of our research we recommend the watershed manager to use arborescent willow *Salix alba* for the bio-technical stabilization of riparian banks. It refers to a native species which is characterized by fast growth in juvenile stages and high stump sprouting. At regular cutting down white willow is of shrubby growth habit with flexible shoots, which prostrate themselves in case of flood waves providing thus erosion control protection to riparian banks (Kaya, 1999; Palmeri et al., 1996; Šimíček, 1992).

We recommend to test (in a semi-industrial scale) the recommended technology of using osier for energy purposes (energy chips) with the consistent evaluation of labour input, costs and yield and thus to prove theoretical calculations obtained on the basis of production analyses in another model region.

In the Czech Republic, there are over 91 000 km watercourses and over 25 000 various water reservoirs. Hydraulic engineering using biological stabilization of riparian banks or the prospective utilization of temporarily flooded areas by suitable willows can represent the indispensable source of energy wood with respect to the engagement of the Czech Republic to increase the proportion of using energy from renewable resources. Moreover, yields for the dendromass can at least partly cover costs for the maintenance of bio-technical stabilization of riparian banks.

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