Amelioration and ecological diversity of forests in Latvia

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An increase in forest cover and higher forest productivity resulted in stock volume increasing from 192 Mm^3 in 1939 to 489 Mm^3 in 1994. The drainage of waterlogged forest lands has contributed positively to this increase.

The sites of the size below 2.0 ha account for 71% of the total number of sites for originally dry site types; for waterlogged sites this percent is 70%, for swampy peatland sites – 68% for drained sites on mineral soils – 70%, for drained sites on peaty soils – 65%.

The index *H* for internal diversity of a forest site, calculated by using the Shenon-Wiener formula, shows the undrained forests to exhibit no higher diversity than the drained ones (H=5.94 and 6.18, respectively).

The share of drained wetland forests should make up 70% of the total amount of these forests.

Keywords: waterlogged forests, drainage, ecosystem, biotope, productivity, diversity, similarity.

Introduction

In the territory of present-day Latvia, the forest has, over the whole post-glacial period, continued as the dominant natural structure. The forest stands have along with changes in climatic and soil conditions, undergone changes in the structure and the volume of wood accumulated..

Paludification is a process that has been going on for millennia. Originally it was connected with groundwater pressure discharge, resulting in numerous spring-laden sites emerging. The areas next to these sites turned into swamp, subsequently merging into larger tracts, which continued to grow and expand in line with the hydrogeological situation on the given area. Paludification affected not only the fertile forest lands but also farmlands long won back from forest, thus making it impossible for man to hold out over vast areas.

It was from a wish to survive and live off the land, that made man purposefully fight back this type of natural disaster, in his belief intolerable. Similar reasoning based on common sense continues also today to act as standing orders for man in his relations with environment. Land amelioration involving the drainage of fields and forests for the sake of improvement, should be treated as a part and parcel of contemporary farming and forestry practices.

How to evaluate the forestry practices, so far used in Latvia, in terms of environmental protection and the conservation of natural diversity?

Following the criteria chosen and the scope of phenomena under analysis, no synonymous evaluation is possible. The volume of wood accumulated in Latvia's forests is constantly growing, whereas the areas under tropical rain forests get reduced and the people in the industrially developed regions are concerned about the abundance of carbon dioxide and shortage of oxygen in the air. In Latvia, an increase in forest cover and higher forest productivity resulted in stock volume increasing from 192 Mm^3 in 1939 to 489 Mm^3 in 1994. It implies that over the said period of time its forests have absorbed 310M t of CO_2 and emitted in the atmosphere 235M t of O_2. Over the last four decades the volume of wood per ha of forest has increased by 90 m^3.

Undoubtedly, the drainage of waterlogged forest lands has contributed positively to this increase. All this goes in a global context.

No less important is the ecological evaluation of these processes on a regional scale, with a bias to the biological diversity in Latvia's forests.

Methodology and Method

An ecological assessment of forest drainage has been done proceeding from the following conclusions:

1. From a biosphere point of view, the importance of forest is increasing along with volume of wood accumulated in live tree stems growing. It implies that the amount of carbon accumulated and oxygen released is immediately correlated to the availability of forest cover and the productivity of it.

2. The diversity of biotopes is the principal precondition for biological diversity.

The biological diversity on the biotope level and the related species diversity may be described in terms of the availability of diversified structure forest sites over the area under analysis. It is to be noted that Latvian foresters identify a forest site following forest type, stand composition, density, age and the productivity index of stand.

In the given study, we analyze the data on wetland forests found in the data base "Latvia's Forest Resources". The set of wetland forests includes both drained and undrained forest lands. Each of 1.5 million forest sites is described by 90 characters, while we make use of 43 only.

The internal diversity of a forest site is described by using the Shenon-Wiener formula, known in information theory and phytocenology (Stugren 1972):

$$H = \sum_{i=1}^{m} p_i \cdot \log_2 p_i ,$$

where H – diversity index; i - a group incorporating similar forest sites; p_i – the relative amount of sites in group i; m – the total number of groups in the area under analysis.

The similarity of forests is described by the Tschekanovsky's coefficient Ks (Миркин 1989):

$$K_s = \sum_{i=1}^{m} 2 \cdot \min (A_i, B_i) : (\sum_{i=1}^{m} A_i + \sum_{i=1}^{m} B_i),$$

where A_i and B_i represent the relative amount of similar sites (groups) in sets A and B.

Falling of an individual site under one of i- groups is determined by: growth conditions (5 options); forest type (4-6 options); dominant tree species (8 options) and its degree of superiority in the stand (2 options); the availability of spruce in the lower storey (2 options); stand age (3 options); stand density (3 options). The maximum possible number of groups within a single type of growth conditions is m_{max} = 1,728, while for the sites analyzed it was between 149 and 686, with the total number of sites between 1,749 and 37,019.

The given method provides for an analysis of internal diversity of forest site on the biotope level, over a fairly large tract of forest and also within the confines of a geomorphological or administrative region.

Discussion

There is analysed the forest structure in three regional forest districts (Ventspils, Limbaži and Cesvaine), located in distinctive geomorphological regions under different climatic conditions (Fig. 1).

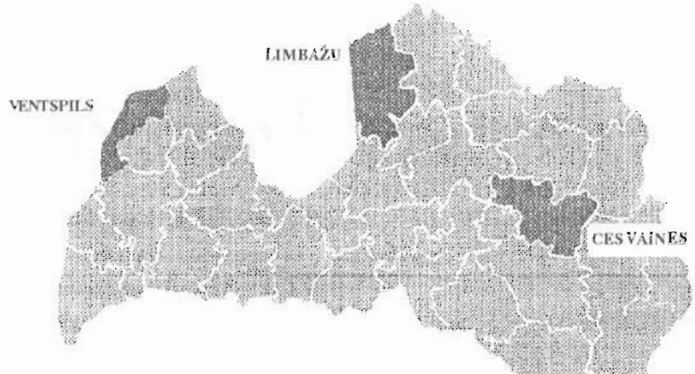

Fig. 1. The location of analysed forest districts.

In each regional forest district, both originally dry and wet sites, including the drained ones, are represented.

Regional forest district	Forest areas represented, in %		
	originally dry	undrained	drained
Ventspils	44	31	25
Limbaži	48	36	16
Cesvaine	47	16	37

The forest areas not degraded due to excessive soil moisture account for less than a half of the total forest area.

The stock volume in mature stands on undrained sites with poor soil aeration is primarily dependent on the amount of nutrients in the soil; this figure is the lowest for Ventspils – 150 m³/ha, with 175 and 221 m³/ha for Cesvaine and Limbaži, respectively.

In drained forests, the stock volume depends on both the potential fertility of soil and the time that has passed after the drainage. In all the regions concerned the age of ditches is similar – between 5 and 60 years, with 30 year-old ditches prevailing.

The stock volume for stands that were drained 50 to 60 years ago and have by now reached exploitable age, is quite high: 290 m³/ha (Ventspils), 315 m³/ha (Cesvaine), 330 m³/ha (Limbaži).

The average stock volume for the drained forest lands is considerably lower: 207 m³/ha (Ventspils), 231 m³/ha (Cesvaine), 270 m³/ha (Limbaži). Out of all the waterlogged forest lands the share that has by now been drained amounts to 45% for the Ventspils district, the respective figures for Limbaži and Cesvaine being 38 and 70%. The above figures demonstrate that the forest land drainage, besides arresting further degradation of forest lands, may considerably increase forest productivity and the volume of wood accumulated, thus contributing positively to the reserves of carbon and atmospheric oxygen, and improving the forest water regulatory properties.

Despite of stringent regulations for forest land drainage with a focus on conserving a good deal of waterlogged and paludal areas and accounting for the interests of water management in the country, the issue of preserving the biological diversity in wetland forests, nevertheless, remains a pressing one.

As regards forest land amelioration by drainage, a compromise solution is the best, since, in view of wood accumulated by forest, a slight decrease in biological diversity on a local level is fully admissible from the point of view of ecology. With this in mind, we will attempt to answer a question, if it is possible to further increase forest productivity coincidentally with an increase in its biological diversity.

An objective information on forest biological diversity is supplied by statistics for the average size of forest site (biotope) (biotope) under differing forest growth conditions as well as that for the number of sites for the given area, 100 ha large in the given case (Table 1). The average size of a site is nearly one and the same in all forest site types: 1.9 ha in originally dry site types; 1.9 ha in waterlogged sites; 2.5 ha in swampy peatland sites; 1.9 ha in drained sites on mineral soils; 2.3 ha in drained sites on peaty soils. The bogs, for whom the average size of a site is 14.3 ha, make an exception here. It is to be reminded, however, that the bogs are broken down into 3 sets: sphagnum, transitional and grass fens, which is not comparable to the division of forest into site types. We remind that the average size of a site in drained forests (on drained mineral soils and drained peatlands) does not exceed that for undrained forests.

The forests in Latvia are distinguished by a mosaic-like structure with the most typical sizes of a forest site below 1.0 ha (Table 2). In originally dry site types the sites of this size make up 39%, this figure for waterlogged sites is 36%, for swampy peatland sites – 39%, for drained sites on mineral soils – 36%, for drained sites on peaty soils – 33%.

Table 1. The occurrence of distinctive forest biotopes

No	Forest site type	Total area, ha	Number of sites	Average size of a site, ha	Number of sites per 100 ha of forest land
	Ventspils Regional Forest District				
1.	Originally dry site types (Sl, Mr, Ln, Vr, Gr)	36,796.6	18,953	1.9	53
2.	Waterlogged forest site types (Gs, Mrs, Dms, Vrs, Grs)	15,552.9	8,241	1.9	53
3.	Swampy peatland site types (Pv, Nd, Db, Lk, Zp, Pp, Sp) *	10,971.7	5,297	2.1	48
4.	Drained site types on mineral soils (Av, Am, As, Ap)	17,013.2	8,791	1.9	53
5.	Drained site types on peaty soils (Kv, Km, Ks, Kp)	3,931.1	1,741	2.3	43
6.	Bogs (Zp, Pp, Sp)	6,045.1	1,106	5.5	18
	Limbaži Regional Forest District				
1.	Originally dry site types (Sl, Mr, Ln, Vr, Gr)	67,002.3	3,7046	1.8	56
2.	Waterlogged forest site types (Gs, Mrs, Dms, Vrs, Grs)	25,416.4	12,519	2.0	50
3.	Swampy peatland site types (Pv, Nd, Db, Lk, Zp, Pp, Sp) *	25,098.7	9,587	2.6	38
4.	Drained site types on mineral soils (Av, Am, As, Ap)	12,331.9	6,626	1.9	53
5.	Drained site types on peaty soils (Kv, Km, Ks, Kp)	9,013.8	4,564	2.0	50
6.	Bogs (Zp, Pp, Sp)	21,044.6	1,262	16.7	6
	Cesvaine Regional Forest District				
1.	Originally dry site types (Sl, Mr, Ln, Vr, Gr)	47,960.3	25,325	1.9	53
2.	Waterlogged forest site types (Gs, Mrs, Dms. Vrs, Grs)	3,622.6	1,862	1.9	53
3.	Swampy peatland site types (Pv, Nd, Db, Lk, Zp, Pp, Sp) *	12,401.5	4,270	2.9	34
4.	Drained site types on mineral soils (Av, Am, As, Ap)	14,019.2	7,266	1.9	53
5.	Drained site types on peaty soils (Kv, Km, Ks, Kp)	23,398.6	9,295	2.5	40
6.	Bogs (Zp, Pp, Sp)	14,741.8	555	26.6	4

* The group comprises bogs of the size below 50 ha.

Table 2. The distribution of forest sites as to their size

No	Site size, ha	Occurrence on a percent basis				
		Dry sites	Water-logged sites	Swampy sites	Drained mineral soils sites	Drained peaty sites
	Ventspils Regional Forest District					
1.	0.1 - 1.0	42.0	38.3	44.7	35.9	36.6
2.	1.1 - 2.0	29.4	33.0	28.4	33.0	31.1
3.	2.1 - 3.0	12.6	14.2	11.5	15.2	12.8
4.	3.1 - 4.0	6.2	6.1	6.4	7.4	6.9
5.	4.1 - 5.0	3.5	3.2	2.9	3.4	3.6
6.	≥ 5.1	6.3	5.2	7.1	5.1	9.0
	Limbaži Regional Forest District					
1.	0.1 - 1.0	38.7	33.3	35.8	35.6	33.5
2.	1.1 - 2.0	32.8	32.8	30.4	33.7	33.9
3.	2.1 - 3.0	14.6	16.0	13.9	15.9	16.6
4.	3.1 4.0	6.5	7.5	7.0	6.9	7.1
5.	4.1 - 5.0	3.1	4.2	3.6	3.6	3.9
6.	≥ 5.1	4.3	6.2	9.4	4.4	6.0
	Cesvaine Regional Forest District					
1.	0.1 - 1.0	37.1	36.3	35.1	34.5	28.3
2.	1.1 - 2.0	33.0	35.3	28.7	34.3	31.0
3.	2.1 - 3.0	14.6	14.8	12.5	15.1	16.6
4.	3.1 - 4.0	6.7	5.2	6.6	7.5	8.9
5.	4.1 - 5.0	3.6	3.2	4.5	3.6	6.1
6.	≥ 5.1	5.2	5.3	12.6	6.0	10.1

The sites whose size does not exceed 2.0 ha account for 71% of the total number of sites for originally dry site types; for waterlogged sites this percent is 70%, for swampy peatland sites – 68%, for drained sites on mineral soils – 70%, for drained sites on peaty soils – 65%.

The above data show the forest drainage to have no effect on the mosaic like pattern of the forest: the site (biotope) size does not increase after drainage and the drained forest lands maintain the same mosaic-like pattern as the undrained ones.

The index H for internal diversity of a forest site, calculated by using the Shenon-Wiener formula reflects the high internal diversity of Latvia's forests in all the site types (Table 3). The diversity is the highest for dry site types ($H_{average}$ = 6.46), followed by waterlogged site types (6.22), drained site types on mineral soils (6.19), drained site types on peaty soils (6.16) and finally by swampy peatland site types ($H_{average}$ = 5.65). On a per-district basis, the Limbaži Forest District, with its forests spread over hills and hollows on nutrient-rich Quarternary sediment, stands out for an extremely high diversity. The Ventspils forests, growing on predominately lean sandy soils, are in this respect more uniform ($H_{average}$ = 5.68). It deserves mention that the undrained forests exhibit no higher diversity than the drained ones ($H_{average}$ = 5.94 and 6.18, respectively). So, the territories with all the forest lands drained (a similar goal has never and nowhere been advanced) would never become biologically more uniform than the territories with undrained forests only.

Table 3. Diversity index H for dissimilar forest growth conditions (m - number of groups, n - number of sites)

Forest site type	Regional Forest District			$H_{average}$
	Ventspils	Limbaži	Cesvaine	
Originally dry site types	H= 5.61 m= 395 n= 189457	7.11 686 3719	6.65 547 25270	6.46
Waterlogged forest site types	H= 5.64 260 8224	6.90 456 12516	6.12 191 1857	6.22
Swampy peatland site types	H= 5.6 185 5179	5.82 243 9584	5.51 177 4239	5.65
Drained site types on mineral soils	H= 5.60 232 8791	6.68 311 6625	6.28 275 7265	6.19
Drained site types	H= 5.91 149 1741	6.36 229 4563	H= 6.22 m= 290 n= 9294	6.16
$H_{average}$	5.68	6.57	6.16	

In this connection a question is raised: to what extent do the phytocenoses of drained forests differ from those of undrained ones? To compare phytocenoses, Tschekanovsky's coefficient *Ks* was used. Modelling was made to show how the waterlogged forests, when a part of them is drained, change as compared to completely undrained ones (Fig. 2).

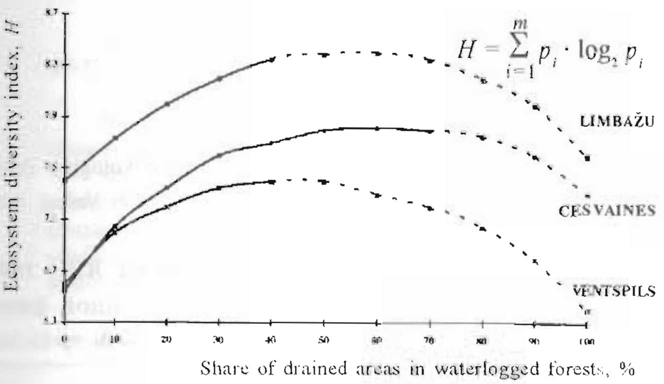

Fig. 2. Similarity (coefficient *Ks*) between undrained forests and partly as well as completely drained waterlogged forests and swampy peatlands (uninterrupted line means drained forests, interruped line means undrained for the present)..

The results, describing the changes in stand structure in partly drained waterlogged forests having 5 to 60 years-old ditches, confirm that the stand structure in drained forests is quite similar to that in undrained ones. Even in the event of all the waterlogged forests drained, the coefficient *Ks,* describing the similarity between the drained and undrained forests, would not fall below 0.70. So, it follows, that the forests similar in stand structure and live ground cover are found in drained as well as undrained areas.

At present, the percent of drained waterlogged forests in the Limbaži, Ventspils and Cesvaine districts is 38, 45 and 70%, respectively. The similarity between the waterlogged forests as of now and the original ones is described by the high values of the coefficient *Ks:* 0.90 (Ventspils); 0.94 (Limbaži); 0.79 (Cesvaine). On the contrary, the value *Ks*=0.23 describes the similarity between the undrained wetland forests of Ventspils and Cesvaine; for Ventspils and Limbaži this value is 0.40, whereas for Limbaži and Cesvaine – 0.24. Thus, the nature-shaped differences in geoclimatic conditions affect the said similarity to a much greater extent than the man's activities, the drainage of waterlogged forest lands included.

With forest drainage activities targeted at higher forest productivity and lesser environment degradation, it is still necessary to find an answer to the question put in the beginning – to what extent is it expedient to drain wetland forests to avoid a loss in forest biological diversity?

It goes without saying that a partial drainage of wetland forests will, all in all, result in a higher diversity along with improvements in other ecological and economic functions of forest. It is possible, by modelling, to state exactly what share of waterlogged forests is worth draining in each individual forest district in order to maintain the biological diversity on the best possible level. To what extent has it already been affected by draining a part of wetland forests?

Modelling for each regional forest district reveals a number of peculiarities as well as similarities (Fig. 3).

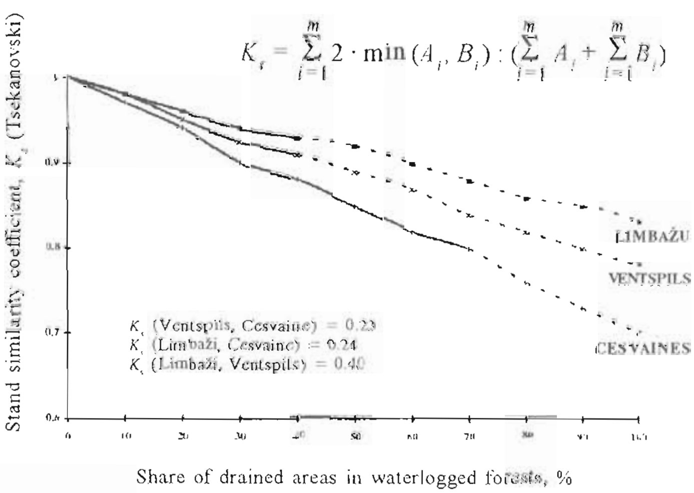

Fig. 3. Ecosystem diversity index *H* accordingly the share of drained areas in waterlogged forests and swampy peatlands (uninterrupted line means drained forests, interruped line means undrained for the present).

The diversity index is the highest with the share of drained wetland forests between 40 and 70%. Even in the event of diversity, taken as the principal criterion, the analysis shows that the share of wetland forests drained should make up 70% of the total amount of these forests. So, in Latvia, where currently the percent of drained wetland forests is below 50 an additional drainage of some 300 thousand ha of wetland forests will only result in an increase in diversity and it maintained on a high level.

Modelling also revealed a need for assessing the forest diversity in each regional forest district separately and predicting changes therein. This is shown by the diversity index curves for Ventspils and Cesvaine (Fig. 3) despite of the diversity index (curves) for the undrained forests in the two districts equal (*H* = 6.60). Furthermore, we have to reckon with the fact that the drainage of wetland forests in Ventspils will not result in a higher internal forest diversity (H_{max} = 7.30) than in the undrained forests of Limbaži (*H* = 7.40). If all the wetland forests of Ventspils were drained, the internal diversity of drained forests (*H* = 6.30) would be even slightly below that for undrained forests (*H* = 6.60).

The given study and the methodology used in it show that it is possible by mathematical methods to objectively evaluate such criteria important for the present-day forestry as the ecological diversity and biological similarity. We hope that the research in this direction will assume an increasing importance in mapping out silvicultural measures and predicting their consequences.

Main conclusions

1. A mosaic-like structure is a typical feature of Latvia's forests: the sites (biotopes) of the size below 2.0 ha account for 70% of the total number of sites. The sites in drained forests are no larger than in undrained ones.

2. The Shenon-Wiener diversity index *H* is suitable for evaluating forest for biological diversity; the forest similarity (dissimilarity) is illustrated well by the Tschekanovsky's coefficient *Ks*.

3. A partial drainage of waterlogged forests entails no decrease in their biological diversity. The biological diversity is the highest in a situation where the share or drained wetland forests does not exceed 70%. An even higher share of wetland forest drained should be treated as a search for compromise between biological diversity, forest productivity and management options.

4. The nature-shaped geoclimatical conditions affect the stand structure in Latvia's forests to a much greater extent than the man's activities, forest land amelioration by drainage included.

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Мелиорация и экологическое разнообразие лесов Латвии

П. Залитис

Резюме

В течение последних шестьдесят лет постоянно расширилась территория лесных земель и возрастала их продуктивностьж в результате того запас древесины, накопленный в древостоях, возрос от 192 млн.м^3 (1949) до 489 млн.м^3 (1994). В повышении продуктивности ведущая роль принадлежит гидротехнической мелиорации избыточно увлажненных лесов и болот.

Лесам Латвии свойствена весьма мозаичная структура: участки леса (биотопы) площадью меньше 2.0 га занимают примерно 70: от всех участков леса. Площадь отдельных биотопов в осушенных лесах в среднем не превышает площади биотопов в неосушенных избыточно увлажненных лесах.

Экологическое разнообразие лесов характеризовано путем использования функции Шенона-Винераж биологическое сходство насаждений хорошо раскрывается при анализе коэффициетов Чекановского.

Экологическое разнообразие избыточно увлажненных лесов возрастает в результате их частичного осушения и наибольшее значение индекса разнообразия наблюдается на территориях, где осушено около 70: избыточно увлажненных лесов.

Природные условия на территории Латвии структуру насаждений обуславливают в гораздо большей степени, чем лесохозяйственная деятельность, включая гидротехническую мелиорацию.

Ключевые слова: избыточно увлажненные леса, дренаж, экосистема, биотоп, продуктивность, разнообразие, сходство.