Comparison and reliability of yield tables of beech stands of western Ukraine and southern Sweden

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Abstract

The forest plays vital role in economy of the most countries. It is a source of wood and food, has recreational, sanitary-hygienic, curative, soil-protective, water regulative and other significances.
Increase of necessities of societies and economies in wood and useful functions of the forest causes new requirements to forestry. Scientific researches, which perfect knowledge about the features of growth, morphology and ecology of stands in general, help to find solution to these requirements. Study about the features of yield of beech stands is necessary and substantial element of general cognition about morphology of the forest, elaboration of scientific theoretical conclusions and applied recommendations concerning utilization of forest resources.
The goal of work was comparison of growth and productivity of beech stands of plane part of western Ukraine and southern Sweden and determination of reliability of the comparable yield tables in both countries relying on data of permanent sample plots.
Analysis of deviations of the basic inventory indexes on all sample plots regarding data of the yield tables and estimate of Student's criterion point at possibility of reliable determining of the inventory indices by using Swedish and Ukrainian yield tables created on basis of site condition.
Site conditions and approaches concerning forming and growing in Ukraine and Sweden do not enable to recommend one of the type of analyzed yield tables for an estimation and prognosis of development of beech stands in both countries.
This research is important first of all for determination of regularities of growth of the beech stands in different climatic conditions. Results demonstrate different character of growth and development of the stands in investigated conditions.

Keywords: European beech (Fagus sylvatica L.), beech silviculture, yield tables, highly productive stands.

Реферат

(Порівняння і достовірність таблиць ходу росту букових деревостанів заходу України та півдня Швеції)

Ліс виступає одним із важливих компонентів біосфери, відіграє важливу роль в економіці більшості країн. Він є джерелом деревини та багатьох продуктів харчування, має рекреаційне, санітарно-гігієнічне, оздоровче, ґрунтозахисне, водорегулююче та інші значення.
Зростання потреб соціуму та економік держав в деревині і корисних функціях лісу ставить нові вимоги до лісового господарства. Воно має забезпечити ці вимоги тому спрямовані головним чином на підвищення продуктивності лісів та ефективності ведення господарства. У розв'язанні цих задач значною мірою допомагають наукові дослідження, які сприяють вдосконаленню знань про особливості росту, морфології та екології деревостанів загалом. Вивчення особливостей ходу росту букових деревостанів є необхідним і суттєвим елементом загального пізнання морфології лісу, опрацювання наукових теоретичних висновків та прикладних рекомендацій щодо використання лісових ресурсів.
Метою роботи було порівняння ходу росту та продуктивності букових деревостанів рівнинної частини заходу України і півдня Швеції та встановлення достовірності порівнюваних таблиць ходу росту, які використовуються в обох країн за матеріалами постійних пробних площ, що закладені у Швеції та Україні.
Аналіз відхилень основних таксаційних показників на всіх пробних площах стосовно відповідних даних таблиць ходу росту вказує на можливість достовірного визначення показників за допомогою таблиць складених на грунтово-кліматичній основі.
Ґрунтово-кліматичні умови та підходи щодо формування та вирощування в Україні та Швеції не дають змогу рекомендувати один із типів аналізованих таблиць ходу росту для оцінки та прогнозування розвитку букових деревостанів в обох країнах.
Вагомістю даного дослідження є насамперед визначення закономірностей росту букових насаджень у різних кліматичних умовах. Результати доводять різний характер росту та розвитку деревостанів в досліджуваних умовах.

Ключові слова: бук лісовий, підходи щодо вирощування бука, таблиці ходу росту, високопродуктивні деревостани.

CONTENT

1. INTRODUCTION

1.1. Features of beech (*Fagus sylvatica*) distribution

Representatives of genus named *Fagus* L. grew in the period of Mesozoic era, and in the period of Cainozoic (about 70 million years ago) beech got maximal distribution in Europe, Asia and America (Magri at al. 2006, Lopez-Merino et. al. 2008). Nowadays such types of *Fagus* are known: *F. sylvatica* L. (Europe), *F. orientalis* Lipsky (northeastern Europe and southwest Asia), *F. japonica* Maxim. (Japan), *F. crenata* Bl. (Japan), *F. enqleriana* Seemen (China), *F. lonqipetiolata* Seemen (China), *F. lucida* Rehd. et Wils. (China), *F. hayatae* Palib. (Taiwan), *F. grandifolia* Ehrh. (North America).

The modern natural habitat of European beech (*Fagus sylvatica*) covers considerable part of western and southern Europe. The area of the beech forests in Europe forms about 19,5 million hectares (EFP 2009). In the north natural habitat of beech envelops the waterside districts of very southern part of Sweden. Eastern part of natural habitat of beech in Europe passes through western part of Poland, south-west regions of Ukraine, especially Carpathian Mountains, and farther, through eastern part of Romania, reaches Bulgaria.

Molotkov (1966) suggested distinguishing the boundary of continuous, insular and single growth of beech on his eastern border. Further distribution of beech in eastern direction, on Molotkov’s opinion (1966), is impeded by his bioenvironmental features. The modern eastern border of continuous distribution does not coincide with ecological.

Beech is a typical element of Central European flora; it successfully grows in a temperate soft climate (Maltsev 1980, Molotkov 1966). The best conditions for beech growth are formed in central part of natural habitat, where average annual temperature is between 6,5 and 8,2 °C, annual precipitation - from 560 to 1340 mm, and relative humidity of air - from 79 to 85% (Molotkov et al. 1973).

1.2. Economic and ecological values of beech forests

The large stocks of wood in beech stands and high characteristics of beech wood provide wide possibilities of utilization. Prevailing kinds of utilization of beech wood are furniture and parquet production; it is used for the production of corps of musical instruments, parts of hunting guns, drawing sets, etc. Its wood is used for dry distillation (obtaining acetic acid, tar, creosote oil and methyl alcohol), chemical processing, burning of coal and in pulp and paper industry. Beechnuts have valuable nutritive properties as they are used in food industry and chemical production (A modern herbal 2009, Missouri botanical garden 2009).

Beech, owing to considerable amount of leaves in a crown, substantially increases annual defoliation, which is good nourishing environment for microflora growth. Defoliation of beech assists in passing of microbiological processes and in decomposing of forest bedding (Gilman and Watson 1993, Boddy and Swift 1984).

Beech forest tracts decrease amplitude of temperatures, increase humidity of air, and consequently create comfortable conditions for rest. According to Kitredzh’s and Lir’s data (Kitredzh 1951, Lir et al. 1974), one gramme of beech leaves evaporates in 3-4 times more moisture during a day than the same amount of a conifer.

The forest clears atmosphere from a dust. The crowns of beech trees annually detain 63 tonnes of dust per 1 hectare, while pine – 36 tones, oak – 56 tones (Gensiruk 1992). According to Maltsev (1980), one tree of beech with 25 m of height, 15 m of crown diameter and 1600 m^2 of leaves area produces

hourly 1,7 kg of oxygen using 2,4 kg of carbon dioxide for this purpose.
Prices for beech round timber in Ukraine vary from 50 to 300 euro per m^3 depending upon quality and dimensions (Interexpo 2009). Prices for beech pulpwood in Sweden are about 30 euro per m^3 and prices for round timber vary from approx. 50 to 250 euro per m^3 depending upon quality and dimensions (Fordaq 2009).

1.3. Significance of beech forests in Ukraine and Sweden

In Ukraine beech is growing on plane (elevation lower than 400 m above-sea level) or mountain (respectively higher) areas. Plane regions such as Podillya and Roztochia, mountain and plane areas of Ukraine are shown on Figure 1.1 (Wikipedia 2009).
The region of Podillya is an historical region in the west-central and south-west portions of present-day Ukraine. It has an area of about 40,000 km², extending for 320 km from northwest to southeast on the left bank of the Dniester river.
Roztochia is a range of hills in east-central Poland and western Ukraine which rises from the Lublin Upland and extends southeastward through the border into Ukraine. The range is approximately 180 km long and 14 km wide (Wikipedia 2009).

Figure 2.1. Podillya, Roztochia, plane and mountain areas of Ukraine (Wikipedia 2009)

Pure beech stands occur rarely and usually in older age in plane conditions of Ukraine (Krynitskiy et al. 2004). Typical admixtures for mixed beech forests are common oak and hornbeam. Beech stands frequently include as admixtures Norway maple, sycamore, common birch, bird cherry, and aspen. Oak and beech form the first storey. Hornbeam, as a rule, grows in the second storey, sometimes with the admixture of more young beech. Such stands are characterized by high productivity and biological stability

Natural beech stands that start forming under forest storey are prevailing in the plane conditions of Ukraine. In accordance with the materials of stratum database of State forestry committee of Ukraine, total area of beech (Fagus sylvatica) forests is 503 thousand hectares, within it stands with beech participation forms almost 166 thousand hectares. Total volume stock of plane beech forests equals 40,7 million m^3. Forest tracts with beech participation equal 8% of forest land and 16,9 % of the area of hardwood trees in Ukraine (Myklush 2009).

The goal of an economic forestry of beech forests in Ukraine is maximal output of business timber. Trees with the biggest yield and the best quality are recommended to be left for final felling.

In Sweden beech is growing on a very southern part of country. Considering that only lowland is relevant for this region, limitation in elevation is absent. Pure beech stands cover about 60 thousand hectares (insignificant part of forest fund), and volume stock forms 21,5 million m^3 (0,7% of all tree species). The annual volume of major harvest is 300 thousand m^3 (Swedish National Forest Inventory 2009).

The goals of an economic forestry of Sweden are stems with high quality. It means 6-8 m straight branch-free stem with 50-60 cm diameter at breast height.

1.4. Aims of the study

The study intends to explore following points:

a) descriptions of the yield tables and methods of yield calculations in Ukraine and Sweden

b) determination of reliability of comparable Swedish and Ukrainian beech yield tables basing upon the data from appropriate sample plots

c) analysis of differences in growth and silviculture methods in both countries

d) comparison of growth and yield of beech in Ukraine and Sweden relying upon the data from yield tables.

2. LITERATURE OVERVIEV

2.1. Features of growing beech stands in Ukraine and Sweden

Pre commercial and commercial thinnings in Ukraine are conducted with the purpose of growing highly productive stands. There are such types of pre commercial thinnings: liberation (is provided till the stand age of 10) and clearing (stand age of 10-20). Commercial thinnings are: reduction (stand age of 20-40), and passage (is provided not later than 10 years before final felling).

The liberation forms desired composition and density. It provides eligible participation of main trees in a stand.

The clearings provide composition and even location of main trees on an area. They form the optimum structure of the future stand and regulate quantitative correlation of certain species.

The reductions create conditions for stem and crown forming of the best trees. Main attention is spared to quality and structure of a stand.

The passages intend to increase the yield of the best trees, marketability of a stands and to shorten time of growing ripe wood. These cuttings improve composition, structure and stability of a stand. The passages can be provided till the final cutting.

Thinning interval of certain thinnings depends upon stand condition. Such terms of intervals are recommended: for liberation and clearing – every 3 to 5 year, reduction – 5-10, passage – 10-15 years. Thinning interval is shorter in the mixed stands. The concrete terms of intervals are set during the forest regulation. Relative density is used in Ukraine to determine density of trees standing in a stand (it is a subjective measurement and relative density 1.0 is characterizing trees density of a normal stand in appropriate conditions). Intensity of thinnings in Ukraine depends upon forest type, composition, age, site index, and, of course, aims of growing. Damaged, wolf-trees and trees without commercial value should be cut according to recommendations. During one step of thinning relative density cannot be decreased lower than 0,7 and more than 85% of total standing volume should be left in a stand. According to my observation, young stands are managed very slightly: few thinnings are provided with small amount of cut trees.

Combined method is chiefly used during the thinnings in Ukraine. It combines principles of trees thinnings from below and above. The division of trees after their economic and biological features is put in basis of this method. Respectively, three categories of trees are distinguished: the best (having a special purpose), auxiliary (helpful) and those, which are to be cut.

Evenly gradual cuttings are conducted in stands with relative density equal 0,6 and more. Three-steps cuttings are conducted in stands with relative density equal 0,9 and more. During the first step relative density can be decreased to 0,7-0,6 with intensity of cutting up to 30% of volume. The second step is conducted in a 5-7 years, relative density can be decreased to 0,5. Two-steps cuttings are conducted in stands with relative density equal 0,6-0,8. Relative density after carrying out of the first step can be decreased to 0,5 with intensity of cutting up to 30% of volume. The eventual step is conducted in a 5-10 years if definite amount of reproduced saplings is present. Cutting area must not exceed 10 hectares.

In accordance with «Rules of clear cuttings in the forests of Ukraine» (1995), final felling is permitted in the age of 100-110 when there are more than 15 thousand of reproduced saplings per 1 hectare. Gradual clear cuttings in three-four steps are usually used in beech stands.

Natural regeneration is common in Sweden. Stand treatment is applied in young stands and later during the commercial thinnings.

The generally accepted typical silviculture program of beech stands is used to achieve goals of Swedish economic forestry. This program is indicated on Figure 2.1 (Carbonnier 1971). As example, data for site index Beech (B32) is indicated on figure below. This index is characterized by dominant height 32 m at the age of 100. These tables begin at that stage in the course of stand development when the first thinning can be performed. To define this stage, the relationship between mean diameter, number of stems and top height has been studied in 25 young stands. The thinning interval has been regulated by making it dependent on the development of the top height of the stand. Standard programme A assumes an increase in top height of ca 1.5 m between each thinning. This leads to a thinning interval which mainly lies within the limits of the material. Programme B has been obtained by approximately doubling both the interval and the thinning yield. The same average basal area has been sought after as that in Programme A. It should be emphasized that yield tables constructed in accordance with Programme B are to be considered as worked examples only. Since the limits of the material have been greatly exceeded in several respects, the calculated stand development involves a considerable degree of uncertainty (Carbonnier 1971). Up to age of 50 thinnings are conducted with 5 or 10 years interval. After 50 the interval can be increased up to 15 years and even allocation of trees on an area is implementing by the decreasing felled trees amount.
The program is reckoned upon the period of 100-110 years or rotation age and foresees, similar to Ukrainian thinnings, pre commercial thinnings regarding forming stands' composition and following thinnings regarding forming expedient density and structure. The wood logging during a regeneration felling, as a rule, is carried out by the method of complete felling.

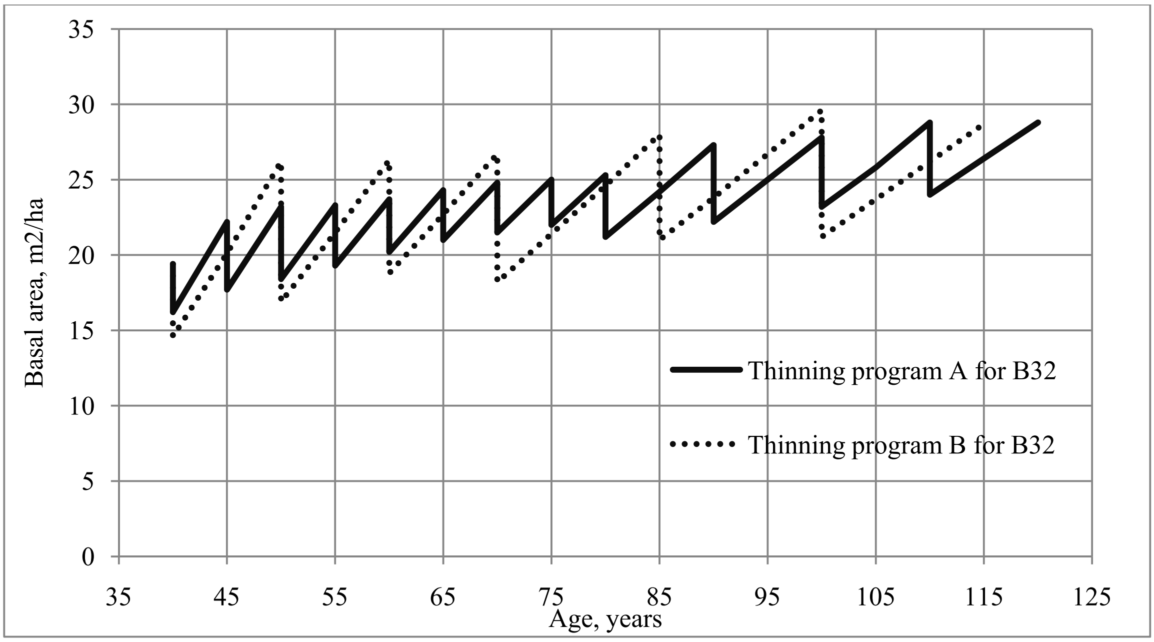

Figure 2.1. Typical silviculture programs of beech (Fagus sylvatica) forests in Sweden

Comparing beech silviculture of both countries, it is impossible to define definite circumstances that stipulate different growth due to absence of typical growing programs for beech in Ukraine. All rules for pre commercial thinnings in Ukraine are much generalized and usually perform only advising character.

2.2. Legislation of beech management in Ukraine and Sweden

There are no restrictions and special law concerning beech management and silviculture in Ukraine. Beech stands after final felling can be regenerated by any tree species.

In Sweden, according to The Forest Act (1994), beech, oak, lime, elm, ash, hornbeam, maple and wild cherry are deemed as “selected valuable broadleaved trees” (noble species) and stands composed of those species after final felling are to be regenerated by appropriate valuable broadleaved species.

2.3. Methods of calculating single tree volumes in Ukraine and Sweden

The volume of a tree in Ukraine is calculating by using volume tables. These tables consist of two variables: diameter and height. Part of volume table for beech is produced in Table 2.1 (Shvidenko et al. 1987). To define volume of a tree one needs basing upon determinate diameter and height find value of a volume in table. For instance tree has volume 0,0957 m^3 if diameter and height are 16 cm and 10 m respectively.

Table 2.1. Part of volume table for beech in Ukraine

Diameter, cm	Height, m											
	10	12	14	16	18	20	22	24	28	32	36	40
8	0,0258	0,0308	0,0357	0,0405	0,0453							
10	0,0396	0,0473	0,055	0,0625	0,07	0,0774						
12	0,056	0,067	0,0779	0,0888	0,0996	0,11	0,121					
14	0,0747	0,0896	0,104	0,119	0,134	0,149	0,163	0,178				
16	0,0957	0,115	0,134	0,153	0,173	0,192	0,212	0,231				
18	0,119	0,143	0,167	0,192	0,216	0,241	0,266	0,29	0.341			
20	0,144	0,173	0,203	0,233	0,264	0,294	0,325	0,356	0,42	0,484		
24	0,206	0,248	0,291	0,334	0,378	0,422	0,466	0,51	0,601	0,692		
28		0,333	0,39	0,447	0,505	0,563	0,622	0,681	0,8	0,922	1,04	
32		0,427	0,5	0,573	0,647	0,721	0,796	0,871	1,02	1,18	1,33	
36			0,623	0,714	0,805	0,897	0,989	1,08	1,27	1,46	1,65	
40				0,869	0,98	1,09	1,2	1,31	1,54	1,77	1,88	2,11
44				1,04	1,17	1,3	1,44	1,57	1,84	2,11	2,24	2,51
48					1,38	1,54	1,69	1,85	2,16	2,47	2,95	3,11
52					1,61	1,79	1,97	2,15	2,51	2,87	3,24	3,61
56					1,85	2,06	2,26	2,47	2,89	3,3	3,72	4,14
60						2,35	2,58	2,82	3,29	3,77	4,24	4,72
…												

The volume of a tree in Sweden is calculated according to the formula (Hagberg & Matern 1975):

$$V_{Swedish} = 0{,}01275\mathrm{d}^2\mathrm{h} + 0{,}12368\mathrm{d}^2 + 0{,}0004701\mathrm{d}^2\mathrm{h}^2 + 0{,}00622\mathrm{dh}^2$$

where $V_{Swedish}$ – volume, dm^3

d – diameter at breast height, cm

h – height, m.

Examples of differences in volumes between above mentioned data are indicated in table 2.2.

Table 2.2. Comparison of data of single tree volume

Diameter, cm	Height, m								
	10	20	30	10	20	30	10	20	30
	Volume of a tree according to Shvidenko et al. (1987) , m^3			Volume of a tree according to Hagberg & Matern (1975), m^3			Deviations of Swedish data regarding Ukrainian, %		
10	0,0396	0,0774		0,036	0,082		9,1	-5,9	
20	0,144	0,294	0,452	0,132	0,276	0,484	8,3	6,1	-7,1
40		1,09	1,65		1,006	1,71		7,7	-3,6
50		1,61	2,46		1,54	2,6		4,3	-5,7

The highest deviations between shown data equals 9,1%, the lowest – 3,6%. It testifies similarity of the different methods of calculating single tree volume.

2.4. Concept of growth models

Growth models assist forest researchers and managers in many ways. Some important uses include the ability to predict future yields and to explore silvicultural options. Models provide an efficient way to prepare resource forecasts, but a more important role may be their ability to explore management options and silvicultural alternatives. Growth models may also have a broader role in forest management and in the formulation of forest policy. Used to advantage and in conjunction with other resource and environmental data, growth models can be used to make predictions, formulate prescriptions and guide forest policy (Vanclay 2001).
A stand growth model is an abstraction of the natural dynamics of a forest stand, and may encompass growth, mortality, and other changes in stand composition and structure. Common usage of the term “growth model” generally refers to a system of equations that can predict the growth and yield of a forest stand under a wide variety of conditions. A model may be considered as a whole stand model, a size class model, or a single-tree model, depending on the detail required, provided and utilized by the model (Vanclay 2001). In this work whole stand models for Ukraine and Sweden (Carbonnier 1971, Dmitriev 1967, Myklush 1986) are used and studied.
Two classes of yield tables are distinguished, normal and variable density tables. Normal yield tables provide estimates of expected yields tabulated by stand age and site index for ideal, fully stocked or “normal” forest stands (Vanclay 2001). The yield tables for fully stocked stands are studied in this work (Carbonnier 1971, Dmitriev 1967, Myklush 1986). Measurement data elaborated by Dmitriev (1967) are done considering site conditions and measurement data elaborated by Myklush (1986) considering beech typology.

2.5. Determination of whole stand yield tables

Whole stand models are those growth and yield models in which the basic units of modeling are stand parameters such as basal area, stocking, stand volume and parameters characterizing the diameter distribution. A yield table presents the anticipated yields from an even-aged stand at various ages, and is one of the oldest approaches of yield estimation (Vanclay 2001). Nowadays modern yield tables include such sort of data: mean heights in metres, mean diameters at breast height (1,3 m) in centimeters, number of stems per 1 hectare, basal area in square metres per 1 hectare, volume of stem wood (in bark) in cubic metres per 1 hectare, mean and current increment of volume in cubic metres per 1 hectare. The yield from thinnings is characterized by the number of stems per 1 hectare, their volume and total volume from the beginning of growth. The sum of stand volume and yield from thinnings determine general productivity of a stand, within it mean and current increments in cubic meters per 1 hectare are defined.

2.6. Peculiarities of beech yield tables in Ukraine and Sweden

Big variety of growth conditions of beech forests entails different approaches concerning construction of the yield tables in Ukraine. Considering all Ukrainian beech forests, the yield tables are formed for plain and mountain conditions, for different types of growth (slow, normal and increasing), for normal, modal and optimum stands, for pure and mixed stands, considering typology (beechen, mixed beech and spruce, mixed beech and oak, etc.) and site conditions. There are universal and regional yield tables for three different regions of Ukraine: plain part of Ukraine, Podillya (also plain but with the best conditions for beech growth), and the Carpathians (see Figure 1.2).
Method of defining site index for naturally regenerated beech in Ukraine is shown in Table 2.3 (Orlov 1928). There are 5 main site indexes used in Ukraine (I, II,...,V)., within main secondary indexes are determined (Ib, Ia, IIa,...,Vb). The highest productivity characterizes site index Ib, the lowest respectively Vb. Site index in Ukraine is determining by the table considering mean height, age and provenance (mean height is graphically weighted on data of 15-20 modal trees).

Table 2.3. Scales of site indices for naturally regenerated beech in Ukraine (Orlov 1928)

Age of birth, years	Stand mean height concerning site indices, m							
	Ib	Ia	I	II	III	IV	V	…
5	3,2 - 2,8	2,7 - 2,4	2,3 - 2,0	1,9 - 1,5	1,4 - 1,1	1,0 - 0,7	0,6 - 0,2	
10	6,4 - 5,6	5,5 - 4,8	4,7 - 3,9	3,8 - 3,1	3,0 - 2,2	2,1 - 1,4	1,3 - 0,5	
15	9,4 - 8,3	8,2 - 7,1	7,0 - 5,9	5,8 - 4,6	4,5 - 3,4	3,3 - 2,2	2,1 - 0,9	
20	12,4 - 10,9	10,8 - 9,3	9,2 - 7,8	7,7 - 6,2	6,1 - 4,6	4,5 - 3,0	2,9 - 1,5	
25	15,1 - 13,4	13,3 - 11,5	11,4 - 9,6	9,5 - 7,7	7,6 - 5,9	5,8 - 4,0	3,9 - 2,1	
30	17,7 - 15,7	15,6 - 13,5	13,4 - 11,4	11,3 - 9,3	9,2 - 7,1	7,0 - 5,0	4,9 - 2,9	
…								
100	38,8 - 34,4	34,3 - 30,7	30,6 - 27,0	26,9 - 23,3	23,2 - 19,6	19,5 - 15,9	15,8 - 12,2	
…								
150	43,3 - 39,2	39,1 - 35,0	34,9 - 30,8	30,7 - 26,6	26,5 - 22,4	22,3 - 18,2	18,1 - 14,0	

To define site index one should find it in the table above considering determinate age and stand mean height. For instance stand corresponds to site index II if it is 30 years old and has stand mean height 10 m.

Dominant height is determining as arithmetical mean value of the 100 trees with the largest diameter. Site index in Sweden is determining considering dominant height at the age of 100, for instance site index Beech32 (B32) is characterized by dominant height 32 m at the age of 100 or site index Beech24 (B24) by dominant height 24m at the age of 100.

The yield tables made by Charles Carbonnier (1971) are widely used in Sweden for the estimation of growth and productivity of beech stands. These yield tables determine silviculture regime, which is periodicity and volume of wood logging. Measurement data elaborated by Carbonnier (1971) are based mainly on observations from 39 permanent sample plots in beech stands (further in work – B32, B28, B24 and B20). They intend to derive yield tables for various site quality classes. With some exceptions, the investigated stands were naturally regenerated. As regards the older stands, the form of regeneration was not known in detail. The younger stands arose, according to notes made at the time of establishment of the plots, following soil scarification under a shelterwood stand, which was then gradually removed (Carbonnier 1971). The yield tables are made considering basis of site index after a dominant height.

The yield tables elaborated by Myklush (1986) for naturally regenerated beech stands of the plain part of western Ukraine in beechen forest type (further in work named Beechen forest type and Forest type of mixed beech and spruce) were constructed for Roztochia (see Figure 1.2). These yield tables are based upon the data from sample plots that were established in mixed stands with relative density more than 0,85.

The yield tables elaborated by Dmitriev (1967) for pure beech stands of first site index (further in work – Site index I and Ia) were composed for western Ukraine overall. These measurement data are based upon 109 sample plots. Relative density of sample plots is more than 0,8.
The yield tables compiled by Tshyk and Hrutsyk (1971) for mixed stands with beech superiority of site index Ia were constructed for western Podillya (see Figure 1.1). These measurement data are grounded on data from 12 sample plots (on Figure 2.2 and in Table 2.5 named Site index Ia and Ib of western Podillya). A summary data of invistigated yield tables are indicated Tables 2.4 and 2.5.

Table 2.4. Generalized data of Swedish yield tables

Name of the yield table	Basis of the yield table	Geogra-phical area	MAI of volume (at culmina-tion) m3/ha y	Age for culmination, year	Standing volume at culmination, m^3/ha	No of comer-cial thinnings	Removed in thinnings after the age of 50 till 120, stems/ha
Sweden:							
B32 (Carbonnier 1971)	site index	southern Sweden	7,8	120	441	4	705
B28 (Carbonnier 1971)	site index	southern Sweden	6,34	120	362	5	974
B24 (Carbonnier 1971)	site index	southern Sweden	5,06	120	300	6	1242
B20 (Carbonnier 1971)	site index	southern Sweden	3,61	120	223	7	No data

Ukrainian yield tables show higher values of MAI but age of culmination is approaching 50 years earlier and even more than in Sweden. Swedish yield tables have the highest volumes at the age of culmination.
Beech stands that correspond to yield tables of site index I and beechen forest type occupy more than 90% of all plane beech forests in Ukraine. Volume growth of most widespread and often used yield tables of Ukrainian plane conditions and Sweden are shown on Figure 2.2.

Table 2.5. Generalized data of Ukrainian yield tables

Name of the yield table	Basis of the yield table	Geographical area	MAI of volume (at culmination) m3/ha y	Age for culmination, year	Standing volume at culmination, m^3/ha	No of comercial thinnings	Removed in thinnings after the age of 50 till 120, stems/ha
Ukraine:							
Beechen forest type (Myklush 1986)	forest type	Roztochia	8,2	70	371	No data	538
Forest type of mixed beech and spruce (Myklush 1986)	forest type	Roztochia	5,7	70	261	No data	463
Site index Ia (Dmitriev 1967)	site index	western Ukraine	10,9	70	525	No data	698
Site index I (Dmitriev 1967)	site index	western Ukraine	8,8	70	423	No data	1128
Site index Ib of western Podillya (Tshyk and Hrutsyk 1971)	site index	western Podillya	8,5 (yield from thinnings not included)	50	426	No data	372
Site index Ia of western Podillya (Tshyk and Hrutsyk 1971)	site index	western Podillya	6,8 (yield from thinnings not included)	60	429	No data	419

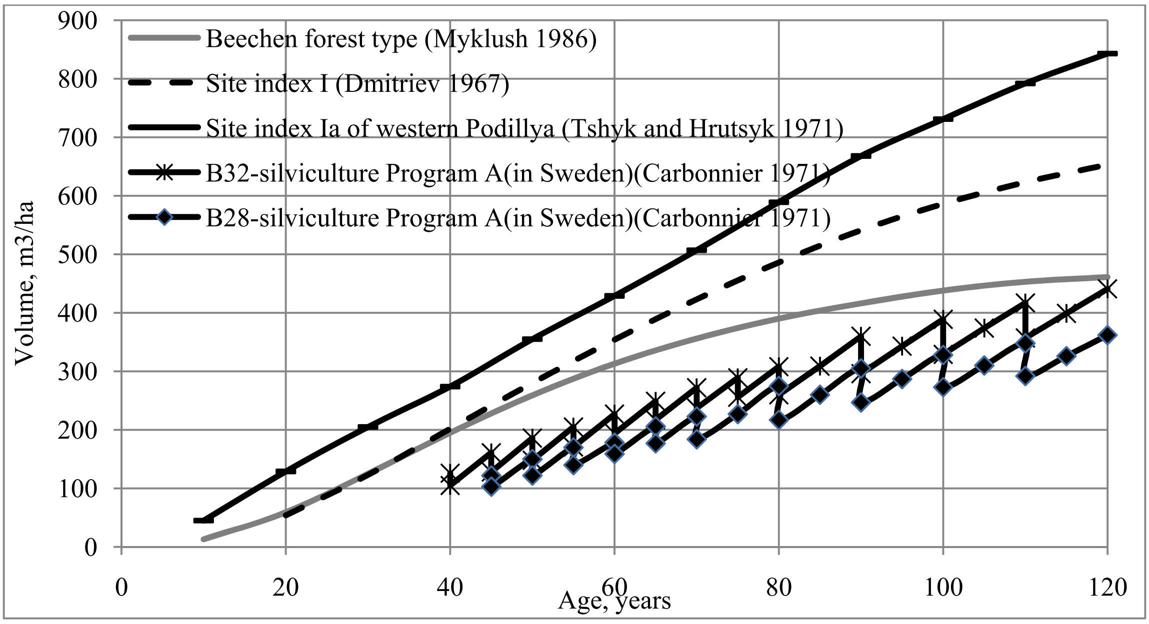

Figure 2.2. Standing volume of different yield tables of plain part of Ukraine and Sweden

Swedish yield tables reflect growth of stands after the age of 40, while Ukrainian tables show development of inventory indices from the beginning of growth. It can be explained due to different methods of yield tables' tabulation. Swedish yield tables are based upon the data from permanent sample plots and all needed information is known from forest management. Ukrainian yield tables are grounded on data from uneven aged sample plots that is received according to the most popular method elaborated by professor Tretyakov (Anuchin 1982). This method includes selection of stands of one natural row of growth and development. Stands are attributed to one natural row if diameters of a stand do not exceed 10% deviation from average diameter line, heights – 15% from average height line, form factors – 6% respectively. According to this method, at least 12 sample plots are to be established for each decade, therefore for the period of 120 years. It should be drawn attention to usage of different heights. Dominant and Lorey's heights are used in the Sweden, and mean heights are relevant for Ukraine.

3. METHODS AND MATERIALS

3.1. Methodology of establishing sample plots

Investigation has been conducted after the materials of permanent sample plots, which have been set up in beech stands by the forestry department of NFUU (National Forestry University of Ukraine).
Permanent sample plots in Ukraine have been set up according to the generally accepted method (Anuchin 1982, Grom 2007) that claims:

a) sample plot must be set up on the most characteristic area in a stand
b) border of sample plot should lay at least in 30 m from the closest opening, road or forest end
c) shape of sample plot can be different but must be easily determined
d) area of sample plot must ensure receiving of reliable results, it means that there are to be more than 400 trees per ha in middle-aged stands and more than 200 in mature stands.

Establishing sample plots consist of following actions:

1) choice of an area and of suitable place on this area
2) sample plot dissociation
3) determination of sample plot direction and side ranging
4) complete enumeration of trees (measurements of diameters of each tree in millimeters)
5) measurements of heights of 15-20 trees from different diameter classes (degrees of thickness)
6) sample plot binding to a definite object outside the plot

Due to windbreaks and thinnings before the investigation period, only 10 sample plots in Ukraine have been left for investigation. Ukrainian sample plots to the greatest extent have rectangular or square form and are situated in Lviv or Ternopol region (see Figure 2.1). Description of Ukrainian sample plots is pointed in Table 3.1.

Table 3.1. General description of Ukrainian sample plots

Plot No	Age, years	Area, ha	Stand Composition	Site index (Orlov 1928)	Condition	Location
UA-1	112	1	Mixed	Ia	After windbreak	Lviv region
UA-2	93	0,5		I		Lviv region
UA-3	68	1		I		Lviv region
UA-4	113	1		I		Lviv region
UA-5	78	1		Ia	After windbreak	Lviv region
UA-6	84	0,25		Ia	After windbreak	Lviv region
UA-7	76	0,46		Ia		Ternopol region
UA-8	65	0,5		Ia		Ternopol region
UA-9	168	1,1		I		Ternopol region
UA-10	61	0,5		Ia		Ternopol region

Size of sample plots is 0,5 or 1,0 ha depending on stand age. Typical admixtures for beech on these sample plots are oak and hornbeam but their share in sum is less than 10% of stand volume.
Site index has been determined accordingly to the scale of site indices made by professor M.M. Orlov (1928), considering mean height and age of the naturally regenerated stand (see chapter 2.6).
Swedish sample plots have been set up by forestry department of SLU (Swedish University of Agricultural Sciences). Overall a very small amount of hornbeams is presented as admixtures for beech on these plots. Description of these sample plots is indicated in Table 3.2.

Table 3.2. General description of Swedish sample plots

Plot No	Age of last measurement, years	Area, ha	Stand composition	Elevation above sea level, m	Site index	Latitude/ Longitude
SWE-860	63	0,25	Pure	90	Beech-34,1	55°37'/ 13°26'
SWE-828	73	0,25	Pure	100	Beech-30,4	55°37'/ 13°25'
SWE-814	87	0,24	Mixed	90	Beech-30,2	55°38'/ 13°56'
SWE-81)	59	0,25	Mixed	100	Beech-29,6	55°38'/ 13°56'
SWE-5033:3	52	0,07	Pure	105	Beech-32,7	55°35'/ 13°29'
SWE-831:2	74	0,1	Mixed	70	Beech-30,3	56°2'/ 13°15'

These sample plots were chosen in maximum correspondence to Swedish site index Beech32 (B32) as they are appointed to check reliability of this index.

3.2. Methodology of control and comparison of the yield tables of Ukraine and Sweden

Control of the yield tables has been done in a graphic after such indices: Lorey's height (mean height for Ukraine), mean diameter, number of stems per ha, basal area, CAI of basal area for Sweden and volume. Maximal relative deviations of each index regarding tabular data have been counted up for characteristic of error value.

Comparison of growth of the beech stands of Ukraine and Sweden has been done in a same way as control. Graphic comparison of materials of sample plots and indexes from the yield tables has been carried out after such characteristics: Lorey's height, mean diameter, number of stems per hectare, basal area, volume, CAI and MAI of volume. With the purpose of using comparable data, Ukrainian mean heights of the yield tables have been converted to Lorey's by using appropriate correlative equation. This equation is based on data from ten Ukrainian sample plots where Lorey's heights have been calculated after the appropriate formula. Mean and Lorey's heights of the same diameters have been put on Figure 3.1.

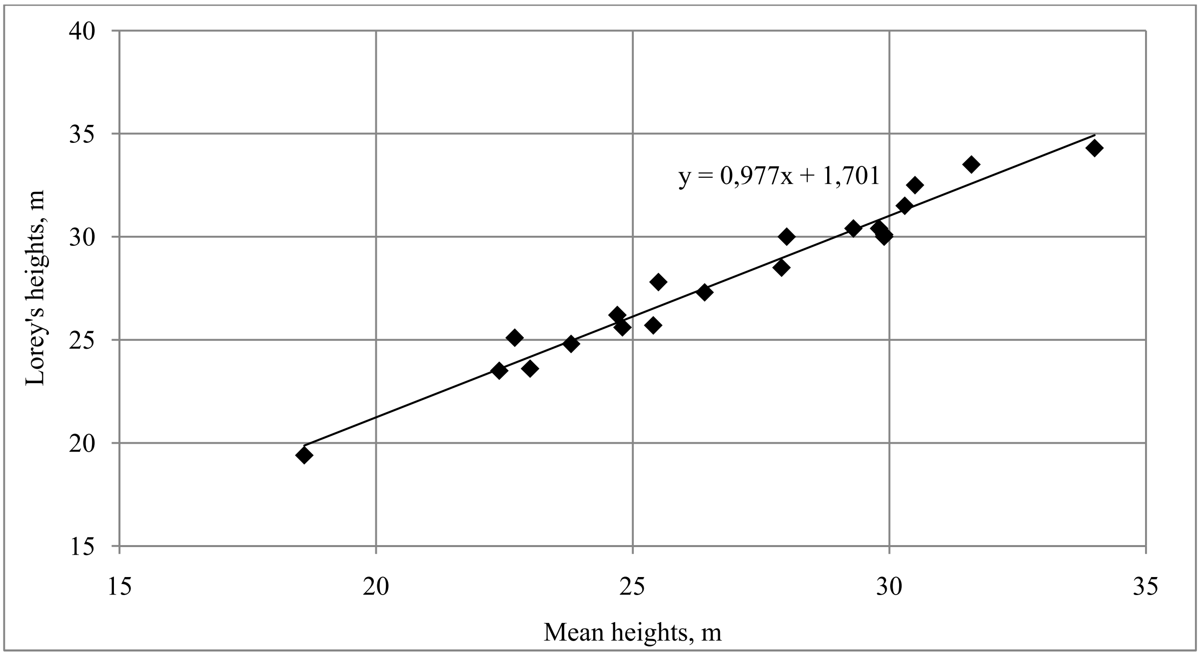

Figure 3.1. Dependence between mean and Lorey's heights based on the data from Ukrainian sample plots

It has been determined that linear dependence exists between the mean and Lorey's heights. Cross-correlation equation and line describing this equation have been shown on figure above.

3.3. Data analyzing

3.3.1. Ukrainian sample plots

There is process of natural growth observed on all Ukrainian sample plots during the investigation period because no silviculture actions were provided. Character of silviculture actions (managing), which were provided before establishment of plots, is not known for us and cannot be defined now.

Repeated measurements on ten Ukrainian sample plots were done by me and my supervisors from Ukraine in summer 2008. In the field the complete list of trees on sample plots was carried out by taking into account such requirements:

- inventory of diameters of sample plots was carried out by 4-centimetre degrees of thickness. Measurements were fulfilled by using the caliper at the spots marked during the establishing of plots.
- diameters at breast height and mean heights of 15-20 trees were measured for a construction of height curve. The data were collected for trees from different diameter degrees.

Following inventory indices of stands were determined by me after the materials of sample plots in Ukraine: mean - height, diameter and basal area; age, site index, volume, composition of a stand, and forest type.

Age of stands was defined by wood borer at the time of plot establishment. Amount of rings on a bore core was calculated in trees from all diameter classes (degrees of thickness).

The diameter corresponding to mean basal area was calculated through the basal area of average tree in stand, based on list of trees after a formula:

$$D_g = 2 \times \sqrt{\frac{G \bullet \pi}{N}},$$

where G is total basal area and N – number of trees per ha.

The Lorey's height or basal area weighted mean height was calculated by taking into account the basal area after the formula $H_L=(h_1g_1+ h_2g_2+.+ h_ng_n)/(g_1+g_2+.+ g_n)$, where h_n – mean height of one degree of thickness, g_n – basal area of the same degree.

The mean height was graphically weighted in relative to mean diameter (D_g) from the height curve based on data from 15-20 trees measured in a stand. It provides accuracy of height determining up to 5%. Generalized data from Ukrainian sample plots are indicated in Table 3.3.

Table 3.3. Growth characteristics of Ukrainian sample plots

Plot No	Year of measurement	Number of stems per ha	Age, years	Diameter, cm	Mean height, m	Lorey's height, m	Basal area	Volume m^3/ha
UA-1	1990	194	94	32,5	29,8	30,4	22,7	305
	2008	159	112	43,2	34	34,3	23,6	368
UA-2	1987	369	72	22,1	22,4	23,5	29	323
	2008	224	93	30,7	29,3	30,4	33	448
UA-3	1985	474	45	15,3	18,6	19,4	19,3	177
	2008	210	68	23,5	23	23,6	20,2	218
UA-4	1991	230	96	43,6	26,4	27,3	29,8	368
	2008	155	113	50,1	30,3	31,5	30,5	458
UA-5	1989	274	59	24,3	25,4	25,7	25,2	320
	2008	154	78	32,3	29,9	30,1	25,2	334
UA-6	1989	441	65	23,9	27,9	28,5	27,8	364
	2008	311	84	32,1	29,9	30	30,6	404
UA-7	1998	360	66	26	23,8	24,8	23,2	280
	2008	320	76	30,2	24,8	25,6	24,1	300
UA-8	1997	638	59	29	25,5	27,8	21	265
	2008	494	65	30	28	30	22,7	306
UA-9	1998	140	163	62,1	30,5	32,5	42,4	597
	2008	127	168	63,6	31,6	33,5	40,3	636
UA-10	1998	259	51	33,4	22,7	25,1	18,5	211
	2008	164	61	39,3	24,7	26,2	20	233

Stand volume was defined after volume tables based on materials of plot's list and volume of one tree that was set after tables considering diameter and height of each tree (see chapter 2.3).

3.3.2. Swedish sample plots

General survey and ordinary measurements of several sample plots has been accomplished by me and my supervisors in 2010. All required measurements were done by foresters from forestry faculty, SLU. Information that include figures of growth for Swedish sample plots is shown in Table 3.4.

Table 3.4. Growth characteristics of Swedish sample plots

Plot No	Year of measurement	Number of stems per ha	Age, years	Diameter, cm	Lorey's height, m	Basal area	Volume, m^3/ha
SWE-860	1986	528	52	22,7	22,3	21,4	215
	1991	388	58	26,3	23,2	21	223
	1996	320	63	28,2	23,9	20	219
SWE-828	1981	468	55	23,1	19,4	19,6	168
	1990	348	64	27,5	22,8	20,7	211
	1999	168	73	38,8	24,8	19,9	219
SWE-814	1977	713	60	19,3	20,2	21	190
	1981	683	64	21,6	21,5	24,9	240
	1987	517	69	23,1	23,9	21,7	231
	1994	404	77	26,1	24,5	21,7	240
	2004	333	87	29,2	25,9	22,3	257
SWE-815	1977	972	55	15,9	19,3	19,4	170
	1981	960	59	17,6	20,4	23,3	215
SWE-5033:3	1990	1971	35	11,2	13,5	19,3	120
	1995	1486	40	12,4	14,8	17,9	124
	2000	1129	46	13,9	17,7	17	144
	2006	886	52	15,1	19,3	15,8	147
SWE-831:2	1973	960	55	14,8	17	16,4	128
	1978	640	60	16,5	18,9	13,7	117
	1986	610	67	20,1	21,8	19,3	190
	1992	410	74	22,9	23,7	16,9	182

All Swedish sample plots have been managed in correspondence to general accepted silviculture program (see chapter 2.1).

3.4. Method of estimation of measurement data reliability

Estimation of reliability of the yield tables has been accomplished after the Student's criterion for both maximal and minimum deviations. Two main inventory indices (diameters and heights) have been chosen for determining reliability of the yield tables.

The number of degrees of freedom has been calculated by formula:

$k = n - 1$,

where k – number of degrees of freedom,

n – minimum amount of measurements made on sample plot.

The estimation of reliability of difference between the investigated heights was executed on 5%-level of meaningfulness with the use of tabular value of Student's criterion (bilateral limitation) with the number of degrees of freedom equal 14 (k=15-1), which is equal 2,145. This value for diameters is 1,96 due to bigger amount of measurements. During the calculation of error of mean values, it was conditioned that for the calculation of inventory indexes of the yield tables is used not less measurements than for sample plots.

3.5. Volume of experimental material

The yield tables of beech stands of Ukraine and Sweden and sample plots are determined as observation material. We have made repeated measurements on 10 permanent sample plots of western Ukraine and have analyzed 6 sample plots of southern Sweden. Descriptions of all sample plots are indicated in Appendix A. Considering expansion of usage and likeness of the yield tables, the yield tables elaborated by Dmitriev (1967) for the pure beech stands of site index I of the plane part of Ukraine, measurement data elaborated by Myklush (1986) for the plane natural beech stands and measurement data for beech stands of site index B32 of southern Sweden (Carbonnier 1971) were analyzed.

None of silviculture actions have been provided on Ukrainian sample plots during the investigation period, except for plots where separate trees were damaged due to windbreak on July 2008. Silviculture measures on Swedish sample plots are controlled and described in detail.

4. RESULTS

Age of stands of sample plots in Ukraine varies from 45 to 168 years, in Sweden – from 25 to 89 years, namely collides on an interval from 45 to 89 years. The Lorey's heights lie within 19,4 - 34,3 m in western Ukraine, and 14,3 - 34,5 m in Sweden. The mean diameters of stands of both countries have also analogous values on a considerable interval. The volumes of stands represent growth features in concrete conditions and are changing from 124 to 366 m^3/ha in southern Sweden and from 177 to 636 m^3/ha in Ukraine.

4.1. Control of the yield tables

4.1.1. Development of stand height

Stand height is important inventory index that characterizes productivity of stand. Mean height is mainly used in Ukraine, using of Lorey's or dominant height is prevailing in European countries. Last two are more stable in comparing to the mean height.

The dynamics of mean heights (Figure 4.1) testifies certain differences in a growth character on sample plots. There is increasing of all mean heights, but its intensity is different comparing to themselves and to the Ukrainian beech yield tables (Beechen forest type and site index I) (see chapter 2.6).

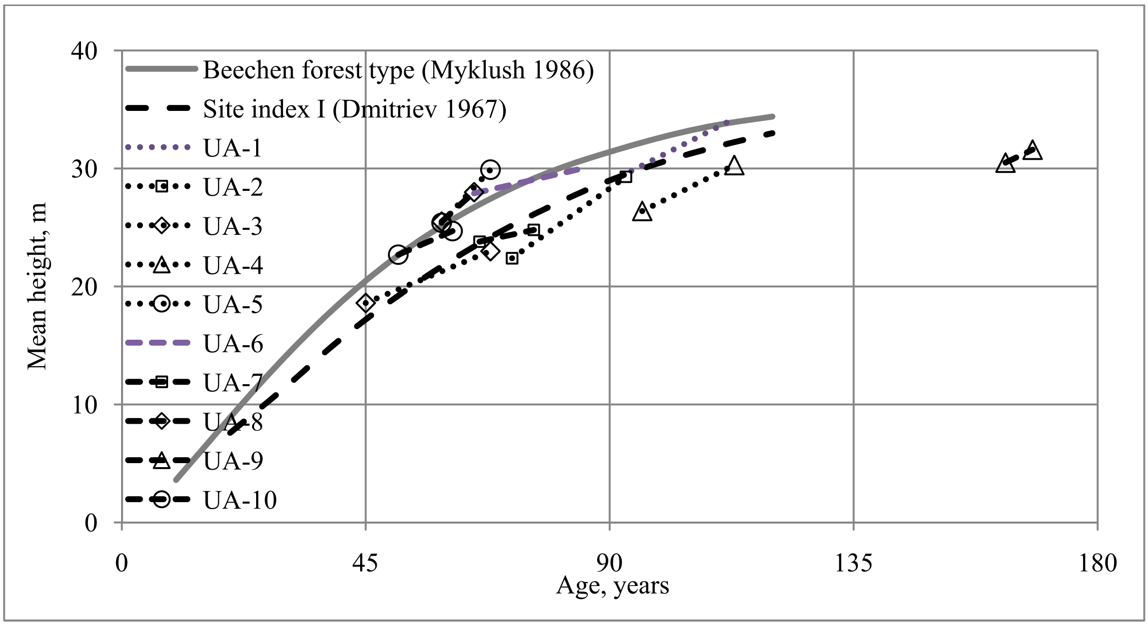

Figure 4.1. Development of heights of beech on Ukrainian sample plots

Lorey's heights are characterized by more appropriate change and smaller changeability of values (Figure 4.2). They are situated upper than basic line of growth - B32 (see chapter 2.6), considering that all of these heights respond to the same site index.

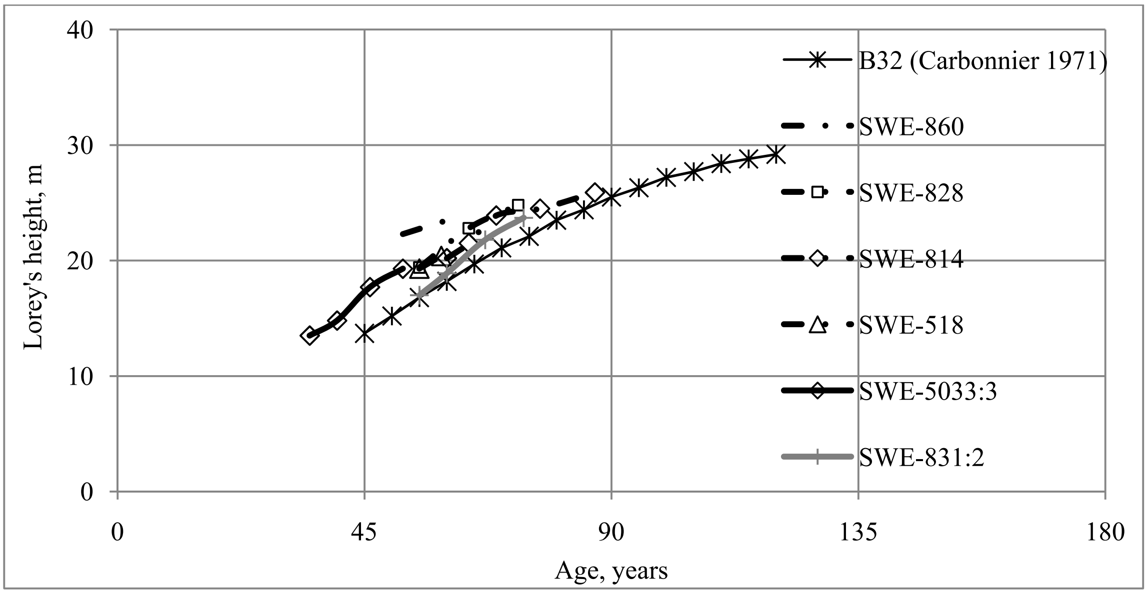

Figure 4.2. Development of Lorey's heights of beech on Swedish sample plots

A difference between heights of the sample plots and yield tables is set basing on relative deviation between analyzable information. The maximal and minimum values of deviations are resulted in Table. 4.1, relative deviations of all investigated information are given in Appendix B.

Table 4.1 Maximal and minimum deviations of heights of sample plots regarding data from the yield tables

Plot No	Age, years	Mean height, m	Lorey's height, m	Deviations regarding tabular data, %		
				Ukrainian		Swedish
				Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-2	72	22,4		-2,22	-4,01	
	93	29,3		-0,06	-1,49	
UA-5	59	25,4		4,31	0,57	
	78	29,9		5,43	0,25	
UA-6	65	27,9		4,61	1,11	
	84	29,9		1,57	-0,44	
UA-10	51	22,7		5,39	0,56	
	61	24,7		2,81	-0,53	
SWE-5033:3	35		13,5			11,91
	40		14,8			5,49
	46		17,7			5,54
	52		19,3			7,01
SWE-831:2	55		17			0,27
	60		18,9			0,64
	67		21,8			1,44
	74		23,7			1,72
	63		22,3			6,30

The biggest deviations are between the sample plots and beech yield tables with silviculture Programme A in southern Sweden, they exceed 10%. Maximal deviations of Ukrainian sample plots regarding yield tables are 5-6%.

4.1.2. Development of mean diameter

The mean diameter determines beneficial structure and sivliculture of a stand. The development of mean diameters in western Ukraine is shown on Figure 4.3 and in southern Sweden on Figure 4.4.

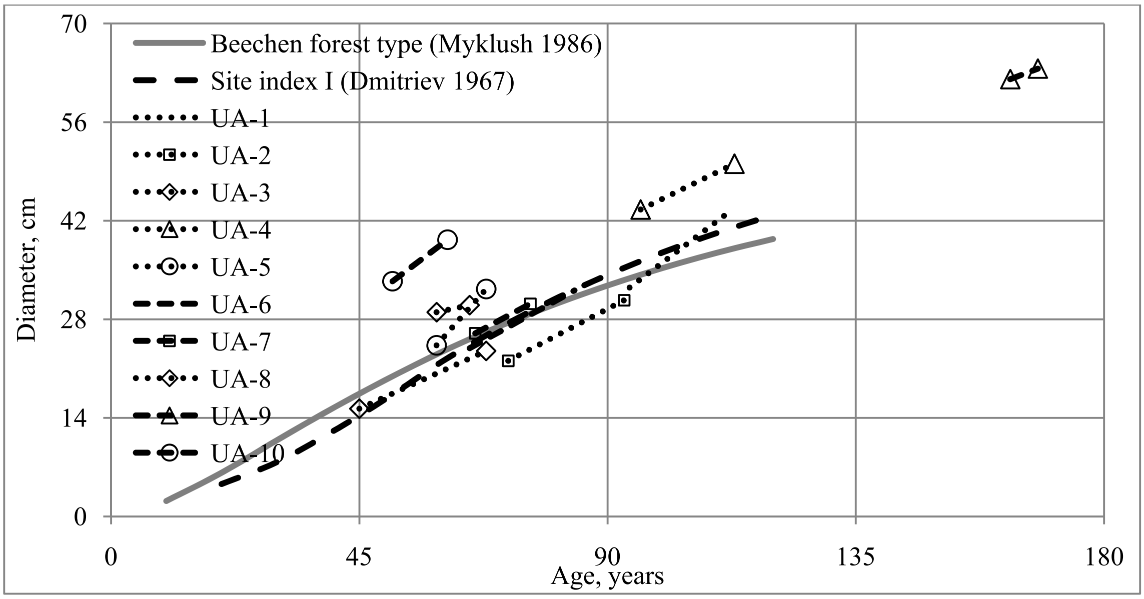

Figure 4.3. Development of mean diameters of beech on Ukrainian sample plots

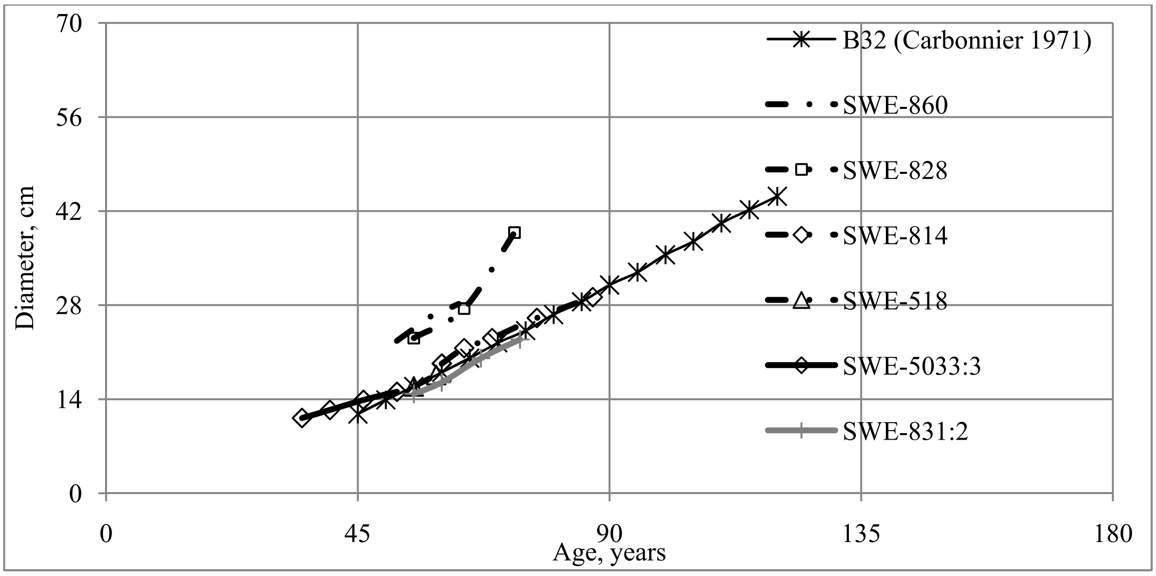

Figure 4.4. Development of mean diameters of beech on Swedish sample plots

Intensive increasing of mean diameters is observed on all sample plots except plots no UA-8, 9 and SWE-831:2 that are situated lower than basic lines of tabular data. The biggest yield of mean diameter is found on sample plot SWE-828, where it forms 15,7 cm during 18 years.
The biggest deviations of the investigated information are found on the oldest sample plot, where the mean diameter almost in two times exceeds tabular value. Minimum deviations of experimental information approach 1% (Table 4.2, Appendix B).

Table 4.2 Maximal and minimum deviations of mean diameters of sample plots regarding data from the yield tables

Plot No	Age, years	Mean diameter, cm	Deviations regarding tabular data, %		
			Ukrainian		Swedish
			Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-1	94	32,5	-8,3	-2,9	
	112	43,2	4,2	15,1	
UA-10	51	33,4	83,3	68,5	
	61	39,3	74	67,3	
SWE-860	52	22,7			53,5
	58	26,3			52
SWE-815	55	15,9			-0,9
	59	17,6			-0,7

The studied materials testify that with age advancing convergence of data of the sample plots and yield tables is observing. Convergence of mean diameters is going slower in comparison to heights.

4.1.3. Reduction of number of stems per hectare

Degree of density characterizes intensity of silviculture or typical regime and features of stand forming in a region. Low density of stands in Ukraine indicates that silviculture has significant influence on young stands, since there were no action provided during the observation period except the plots with wind-fallen trees (Figure 4.5).

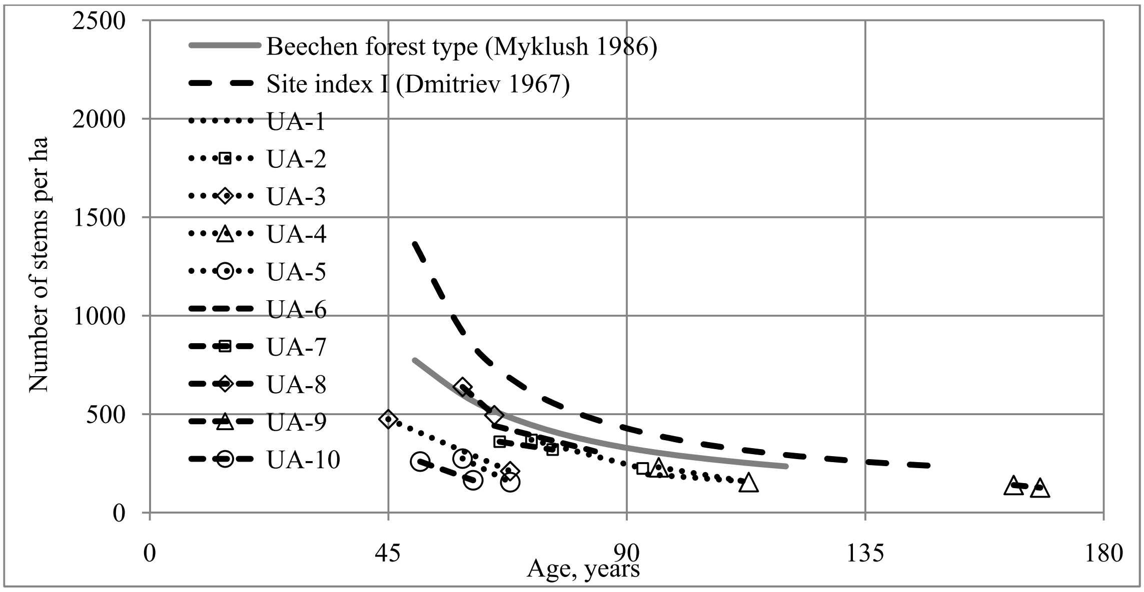

Figure 4.5. Reduction of number of stems per hectare on Ukrainian sample plots

The highest density is observed in the stand that is 69 years old – 638 stems/ha. The oldest stand naturally has the lowest density.

From comparison of stems density it is seen that number of stems on Swedish sample plots is considerably nearer to tabular information of line B32, but principally is lower (Figure 4.6). The least number of stems is noticed on sample plots SWE-860 and SWE-828, which obviously were intensively felled early in life.

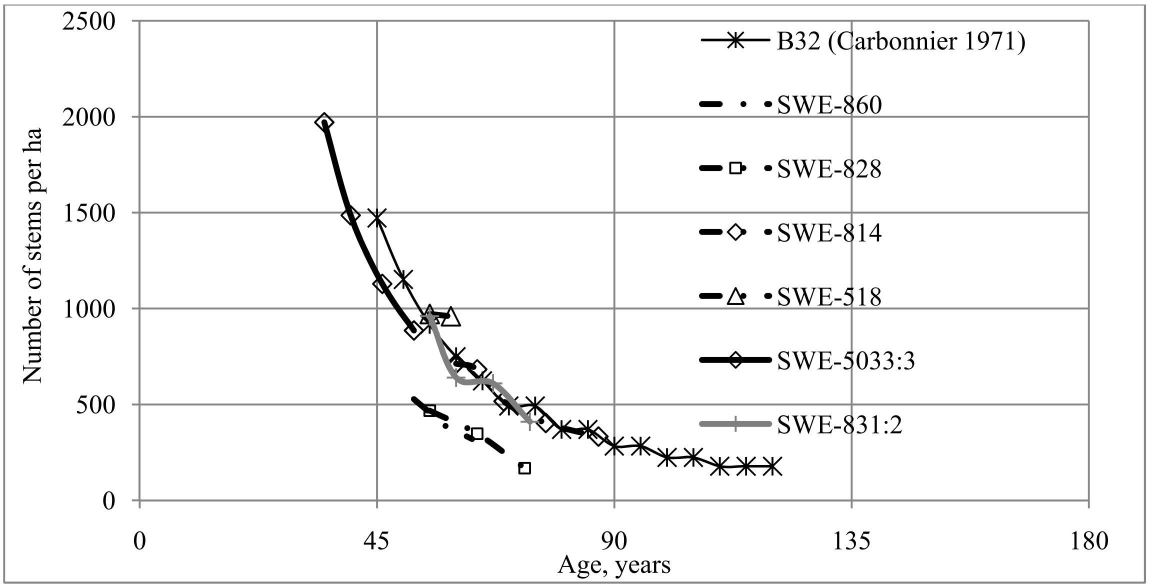

Figure 4.6. Reduction of number of stems per hectare on Swedish sample plots

Numbers of stems on sample plots SWE-814 and SWE-831:2 are the closest to tabular information, deviations do not exceed 12%. Number of stems per hectare exceeds 20% on others plots. Maximal deviation, almost 89%, is found on the oldest sample plot UA-9.

4.1.4. Development of basal area and CAI of basal area.

Absolute relative density as well as density of stands determines character of stand forming. Character of development of basal area is resulted on Figures 4.7 and 4.8.

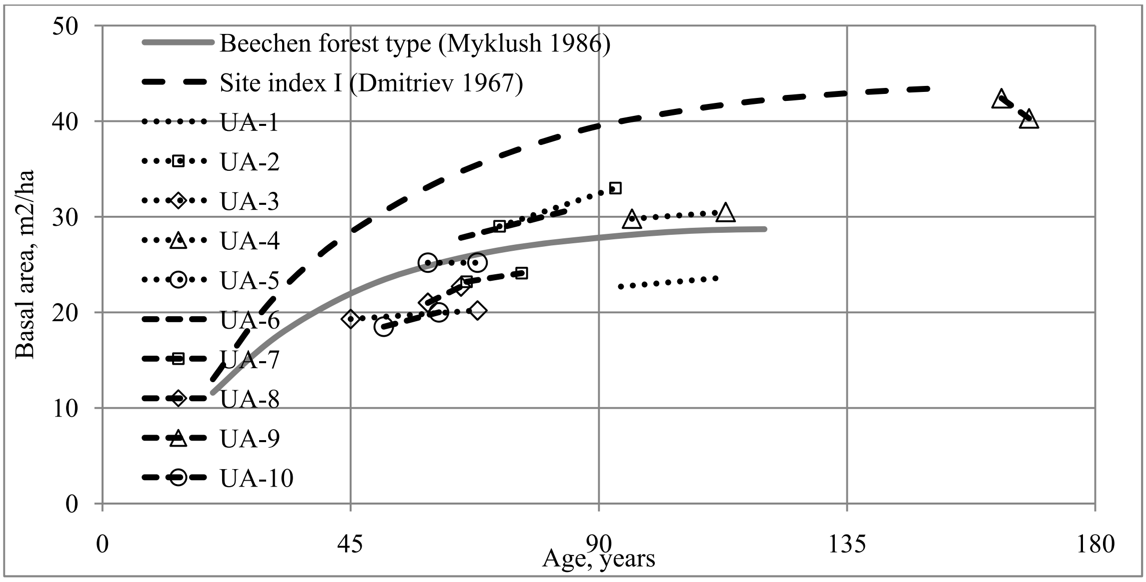

Figure 4.7. Development of basal area on Ukrainian sample plots

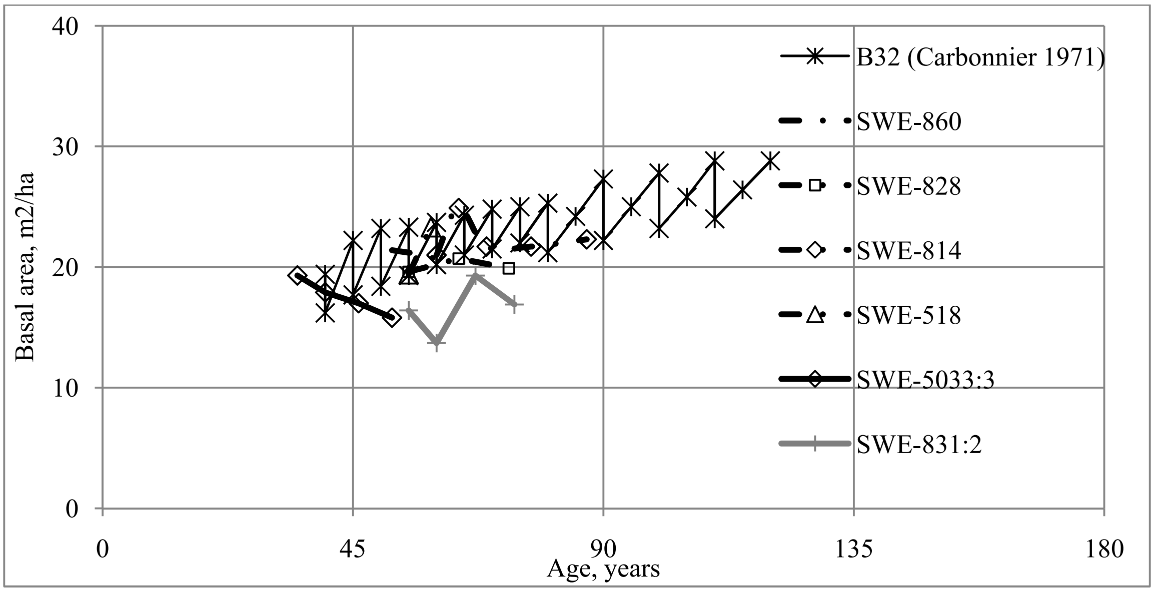

Figure 4.8. Development of basal area on Swedish sample plots

Development of basal area on ten Ukrainian plots shows different rapidity of their growth with age advancing. They have nearer values to the yield table named Beechen forest type. Development of basal area on Swedish sample plots represents character of silviculture that has been conducted in the investigated stands.

Current annual increment (CAI) shows the increment over a period of one year at any stage in the stand's history. Character of CAI development on Swedish sample plots is shown on Figure 4.9.

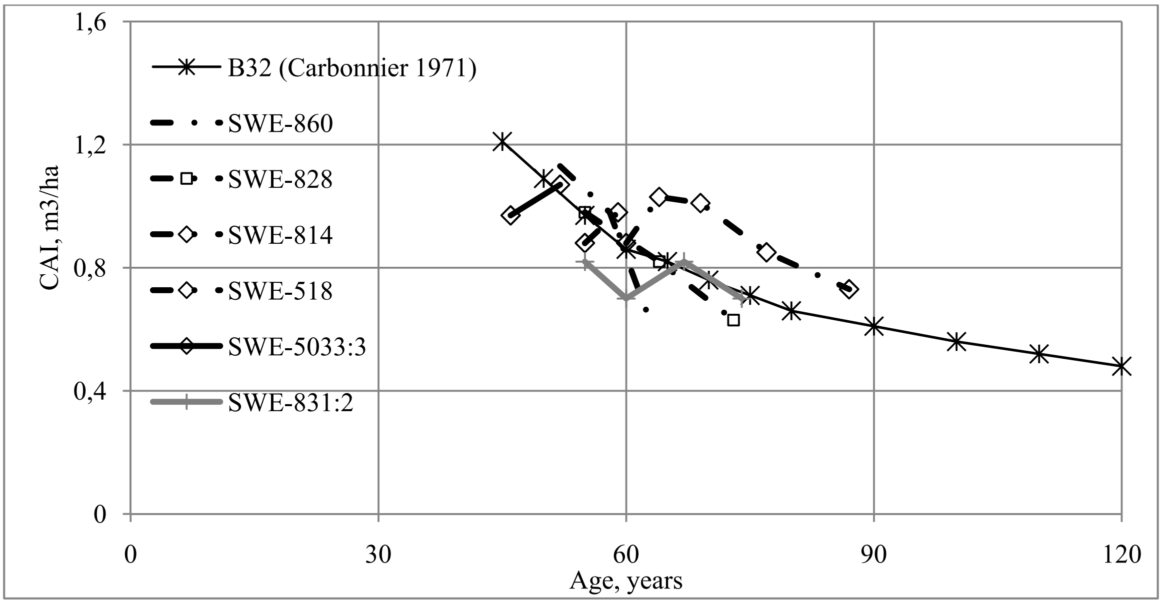

Figure 4.9. Development of CAI of basal area on Swedish sample plots

Only data from plot SWE-828 show considerably higher values of CAI in comparison to basic line of growth B32.

4.1.5. Development of stand volume

Stand volume on sample plots no UA1-10 is increasing with different intensity (Figure 4.10), and on Swedish sample plots is changing in accordance to thinnings (Figure 4.11).

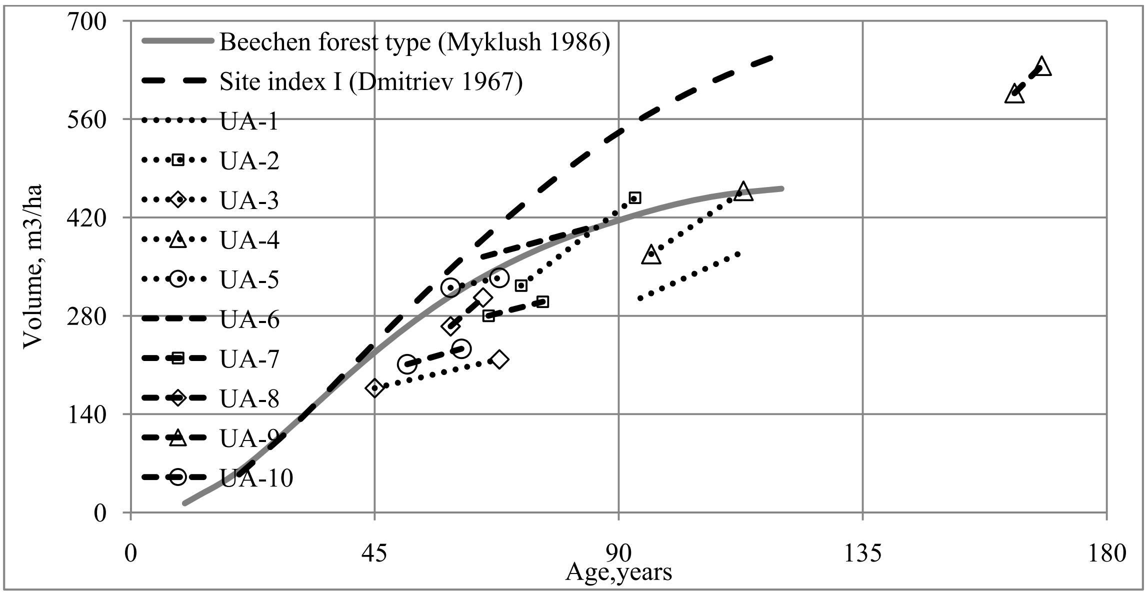

Figure 4.10. Development of stand volume on Ukrainian sample plots

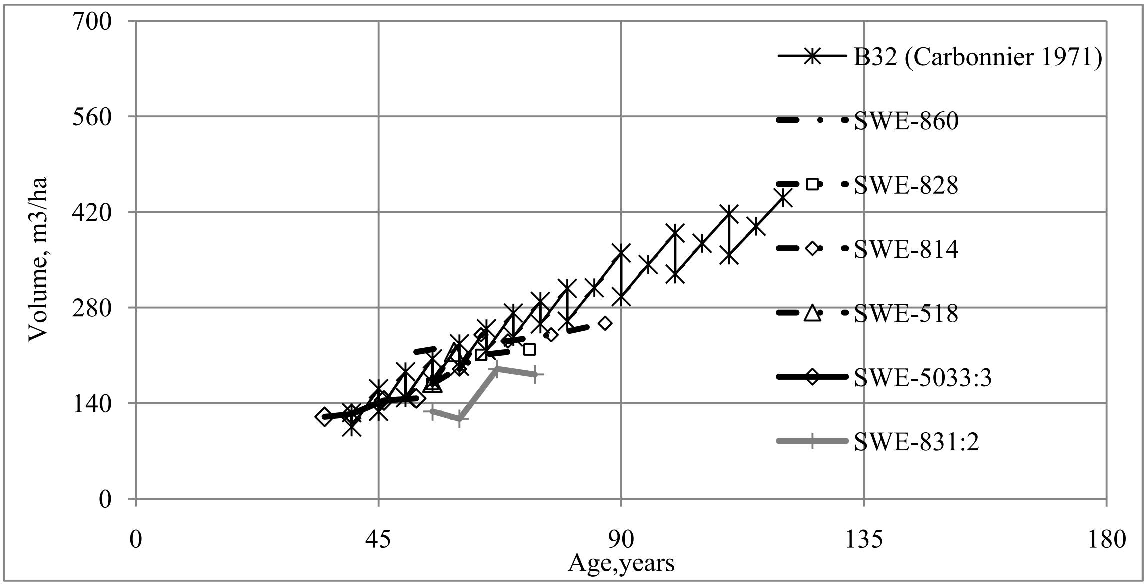

Figure 4.11. Development of stand volume on Swedish sample plots

The volume represents features and intensity of development of invetory indices. The highest intensity of volume growth is peculiar to stands of sample plots UA-3 and UA-4. Development of stand volumes on Swedish sample plots shows that silviculture has significant influence on stock forming. Deviations of the volumes on sample plots regarding tabular data mainly exceed 10%, and maximal values reach 60-80% as it is observed on sample plots SWE-860 and SWE-5033:3. With growth advancing gradual convergence of actual and tabular data is noticed.

4.2. Reliability of the yield tables based on data from sample plots

Reliability of the yield tables has been defined after heights and diameters. Student's criterion has been used for this purpose. Actual values of criterion are pointed in Appendix C. Maximal and minimal actual values of Student's criterion after heights and diameters are indicated in Tables 4.3 and 4.4 respectively.

Tables 4.3. Minimal and maximal actual values of Student's criterion after diameters

Plot No	Age, years	Mean diameter, cm	The actual values of Student's criterion calculated between the values of sample plots and yield tables		
			Ukrainian		Swedish
			Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-4	96	43,6	4,92	6,39	
	113	50,1	13,48	20,14	
UA-6	65	23,9	-0,10	-0,24	
	84	32,1	0,10	0,42	
SWE-828	55	23,1			1,64
	64	27,5			2,07
	73	38,8			6,99
SWE-815	55	15,9			-0,03
	59	17,6			-0,02

It is seen from Table 3.4 that diameters of sample plots UA-6 and SWE-815 (Ukrainian and Swedish respectively) show the most reliable difference concerning the yield tables. Maximal actual values of Student's criterion show sample plots UA-4 and SWE-828.

Tables 4.4. Minimal and maximal actual values of Student's criterion after heights

Plot No	Age, years	Height, m	The actual values of Student's criterion calculated between the values of sample plots and yield tables		
			Ukrainian		Swedish
			Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-5	59	25,4	4,31	0,57	
	78	29,9	5,43	0,25	
UA-9	163	30,5	-1,05	1,89	
	168	31,6	-0,17	3,86	
SWE-5033:3	35	13,5			11,91
	40	14,8			5,49
	46	17,7			5,54
	52	19,3			7,01
SWE-831:2	55	17			0,27
	60	18,9			0,64
	67	21,8			1,44
	74	23,7			1,72

Taking into account heights, the most reliable difference is observed on sample plots UA-5 concerning the yield tables of Beechen forest type, on sample plot UA-9 concerning tabular data of Site index I and on SWE-831:2 concerning Swedish yield table.

Actual values of Student's criterion after heights are changing within 0,19 – 11,91. Values after diameters have higher changeability, the maximum value equals 20,14. Higher values of criterion are inherent in Ukrainian sample plots.

4.3. Comparison of beech management of western Ukraine and southern Sweden based on data from yield tables

4.3.1. Number of stems per hectare

The dynamics of density affirms that beech stands in Ukraine and Sweden are grown with the different number of stems per hectare (Figure 4.12).

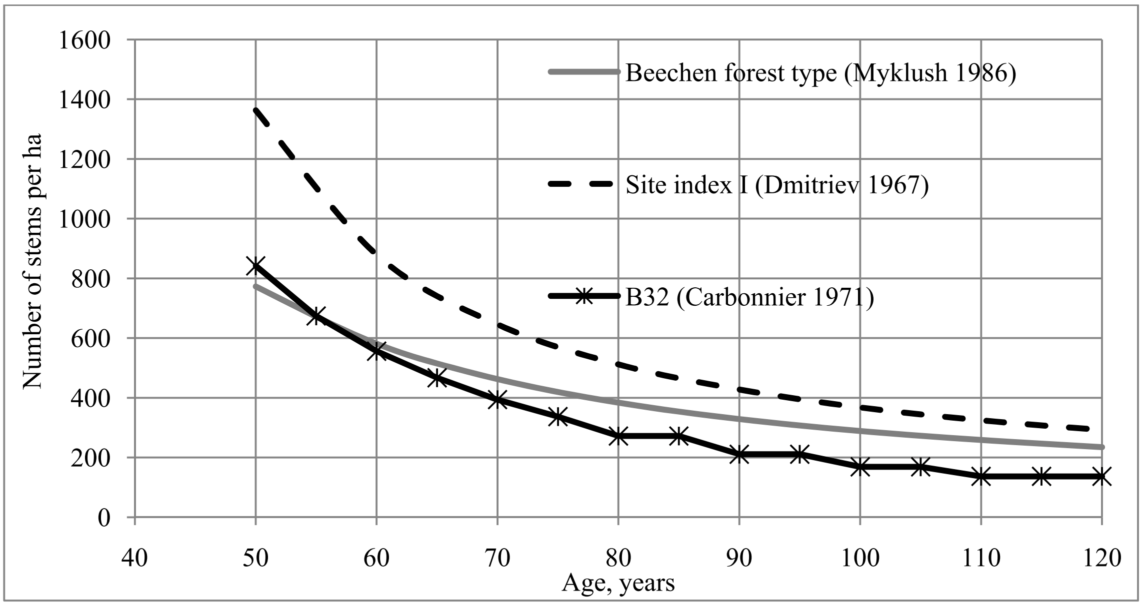

Figure 4.12. Comparison of beech stands after number of stems per ha based on data from the yield tables

The highest density of stands is relevant for the Site index I during the whole period of investigation. Other two lines (Beechen forest type and B32) (see chapter 2.6) have nearer values of number of stems per ha but after the age of 60 difference is increasing up to 100 stems/ha in 120 years.

4.3.2. Basal area

Pure beech stands in Ukraine (Site index I) testify that their forming can be carried out at high absolute relative density already from 20 years (Figure 4.13).

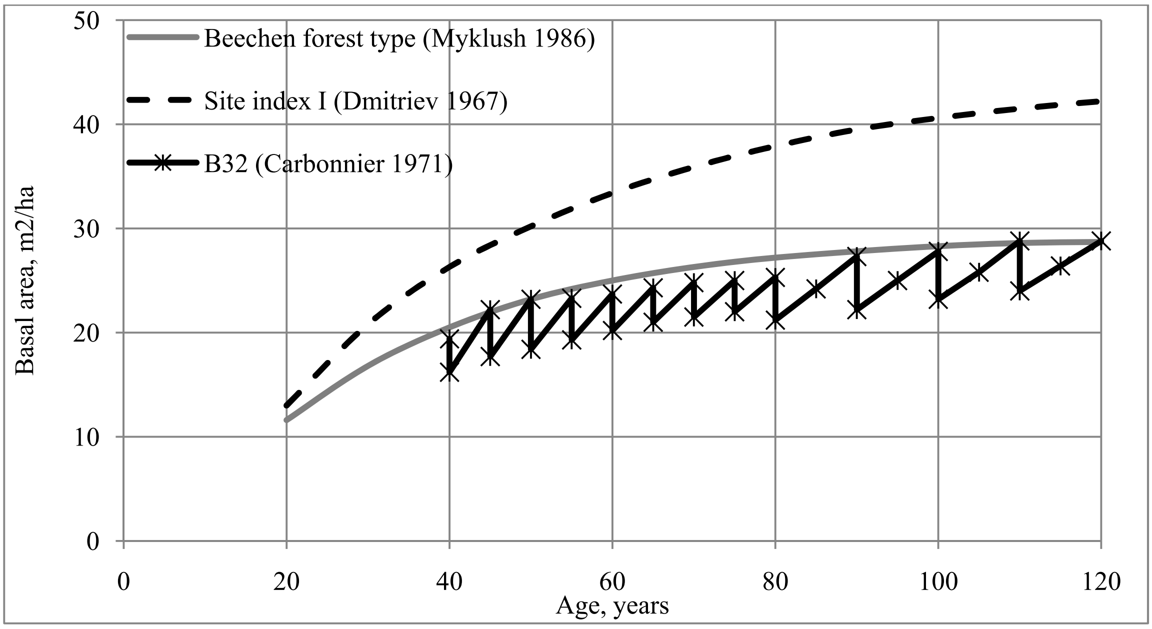

Figure 4.13. Comparison of beech stands after basal area based on data from the yield tables

Site index I have the highest values of basal area. Different bases of tabulating yield tables stipulate difference in 18-20% between the lines B32 and Beechen forest type. A convergence of these lines is observed with the age advancing.

4.3.3. Volume

Ukrainian beech stands have higher values of volumes in comparison to Swedish stands (Figure 4.14). In the age of 40 values of volumes in Ukraine are almost in two times higher than in Sweden. After 40 beechen forest type is characterized by high increase of volume; it stipulates the difference in 190-210 m3/ha in the age of 120.

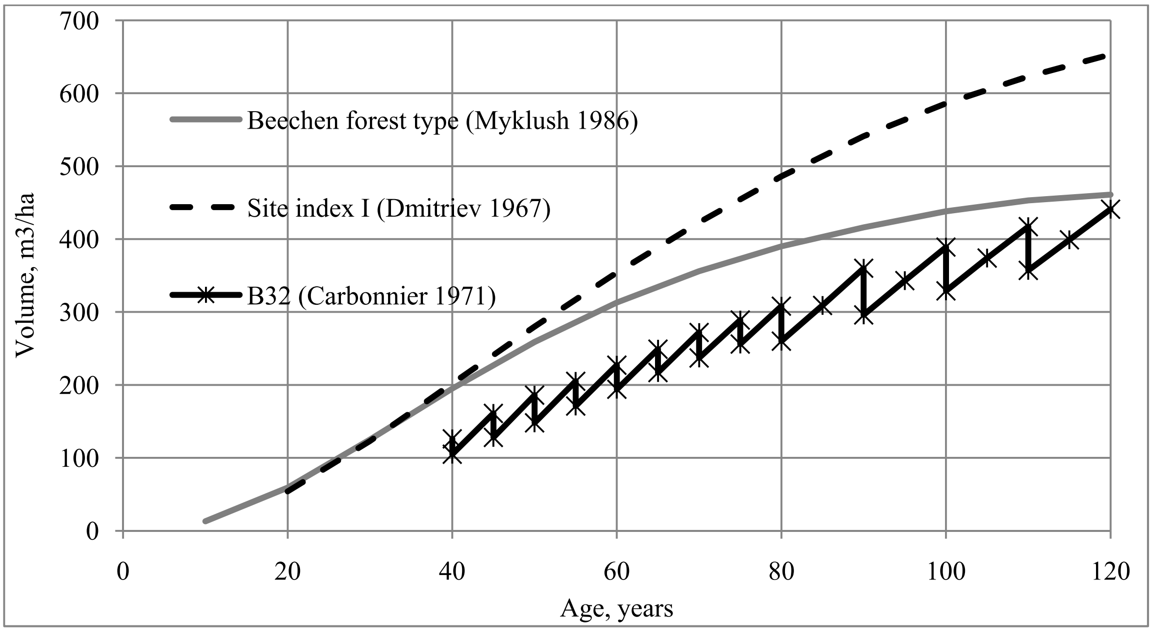

Figure 4.14. Comparison of beech stands after volume based on data from the yield tables

By adjusting density of beech stands and character of their growth it is possible to attain growth of volumes; as it is seen from figure above difference between the lines B32 and Beechen forest type equals 20 m^3/ha in the age of 120.

4.4. Comparison of the yield tables of western Ukraine and southern Sweden

4.4.1. Height

The dynamics of stands growth after a height and other inventory indexes represents influences of soil conditions and character of silviculture; comparison of growth enables to set certain features. Comparison of growth after the heights of beech stands is shown on Figure 4.15. It is obvious that there is significant difference between the analyzed heights up to age of 100 years. In the age of 40 and 60 difference in Lorey's heights between the lines B32 and Site index I exceeds 2 m, and in comparing to Beechen forest type reaches 5 m.

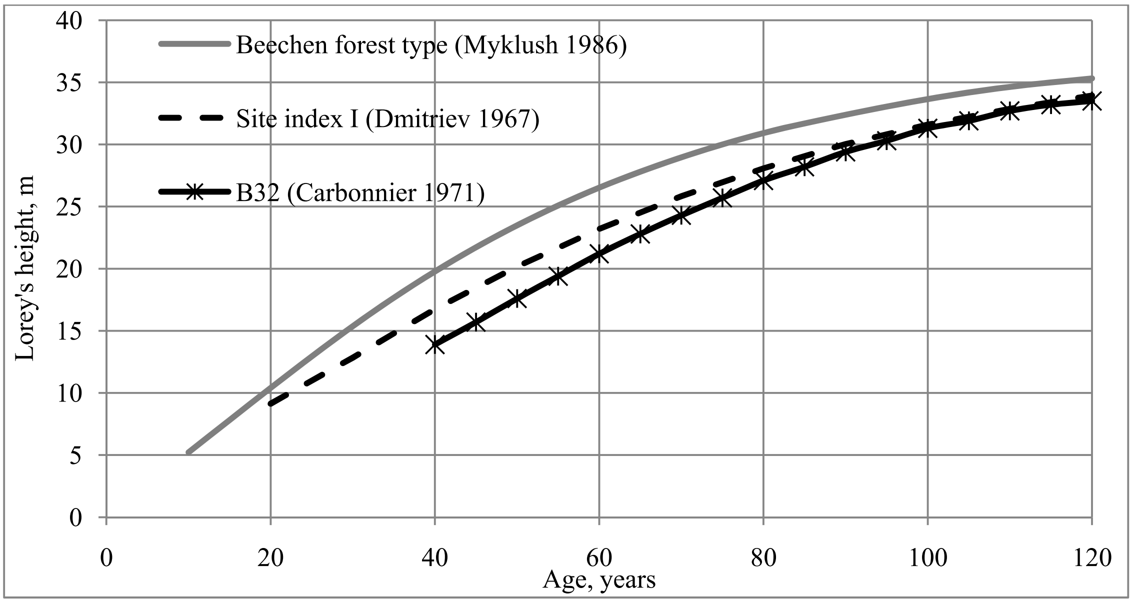

Figure 4.15. Comparison of beech stands after Lorey’s height based on data from the yield tables

Swedish beech stands, which are described by line – B32, have nearer values of Lorey’s heights to Ukrainian stands which respond to site index I.

4.4.2. Diameter

Information resulted on Figure 4.16 points on different approaches concerning growth and management of beech stands in Ukraine and in Sweden, especially in older age. There is no significant difference in growing until age of 80. Beechen forest type is characterized by somewhat higher values of mean diameters than site index I (the difference does not exceed 10%). Beech stands, which grow in Sweden and are characterized by line B32, have almost the same development of mean diameters as Ukrainian stands of first site index but only until 80 years.

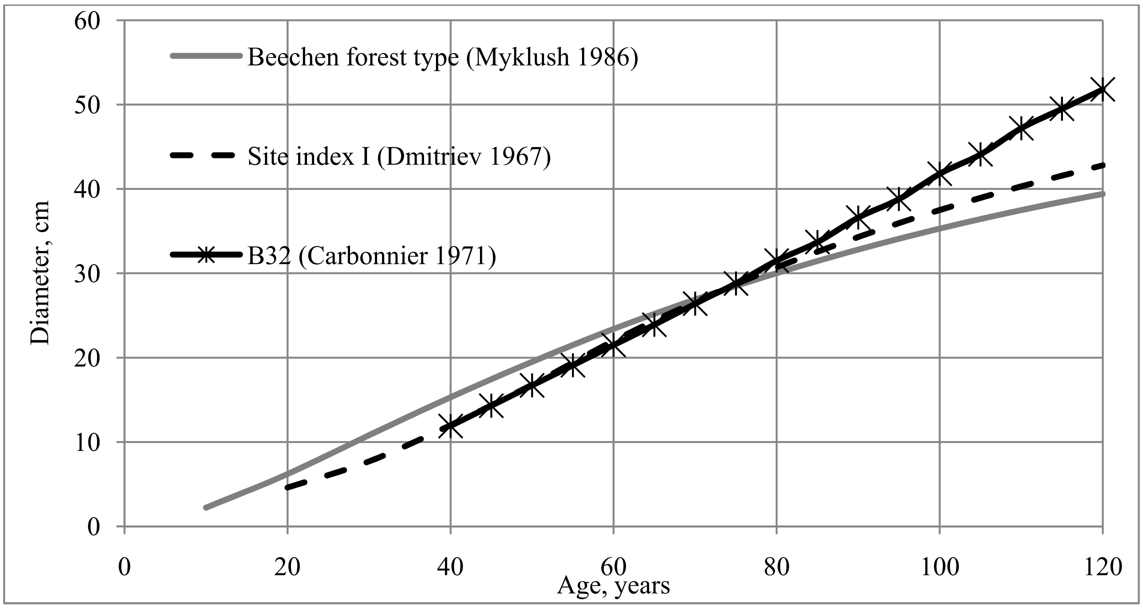

Figure 4.16. Comparison of beech stands after mean diameter based on data from the yield tables

After 80 years beech stands in Ukraine reduce intensity of growth after diameter due to silviculture which was provided before investigation period. Difference of diameters between investigated beech stands in Ukraine and Sweden is equal 10 cm in 120 years.

4.4.3. CAI and MAI of volume

Higher values of CAI after the age of 50 in comparison to Ukrainian yield tables are relevant for Swedish table B32, difference is increasing consistently up to age of 120 (Figure 4.17). At the age of 120 difference between Ukrainian and Swedish yield tables is equal 4 m^3. During the period within 50 and 55 years all three yield tables are showing almost the same values of CAI.

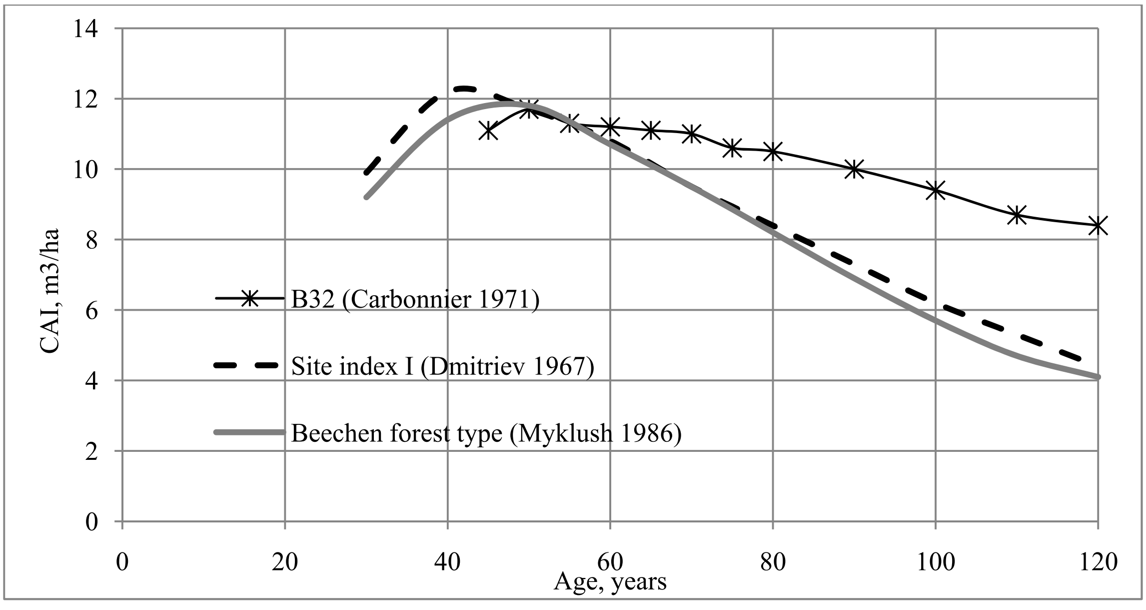

Figure 4.17. Comparison of beech stands after CAI of volume based on data from the yield tables

Mean annual increment shows change of inventory index on average during 1 one year of certain period of life. The lowest values of MAI up to age of 105 are inherent to B32 (Figure 4.17).

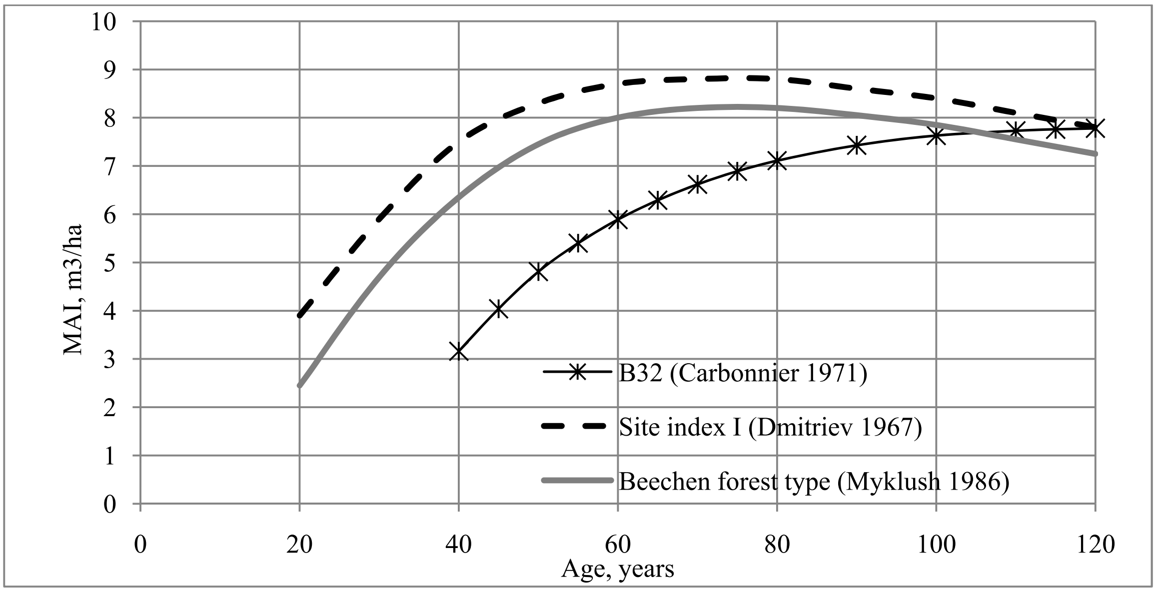

Figure 4.17. Comparison of beech stands after MAI of volume based on data from the yield tables

After the age of 105 B32 gets higher values than Beechen forest type and at the age of 120 is equal to value of Site index I. During the whole period of growth Beechen forest type demonstrates approximately 10% lower values of MAI than Site index I. Figure above shows that culmination of MAI of volume in Ukranian yield tables comes at the age of 70 and in Swedish yield table at the age of 120.

5. DISCUSSION

The yield tables characterize growth and productivity of stands of a certain species and, as a rule, are based on descriptions that make one natural row of growth and development. Such rows, mainly, are determined by taking into account growth of stands after the basic inventory indices – height, diameter and second form factor. Characteristics of growth of mean or dominant trees are used for ascertainment of the same type of growth. Thus, inventory indexes in the yield tables depend on that as far as successfully stands of one row were selected.
Long-term observations can provide the receipt of the detailed descriptions of dynamics for basic inventory indexes but they also have shortcomings. Basic of these are absence of confidence in long-term storing of stands and vagueness concerning internal structure of the stands' characteristics (after composition, density, silviculture, etc).
The main factors, which can influence growth, are site conditions and individual peculiarities of stand structure. It is necessary to take into account also climatic descriptions of growth and development periods (Zagreev 1978).
Ukrainian sample plots are set in stands with different site indexes; it stipulates certain deviations regarding data from the yield tables of one site index or forest type. Swedish sample plots are selected concerning similarity to site index B32. Generally, all sample plots are representative and show similar to the investigated yield tables growth.
Sample plot no UA-9 is characterized by the oldest age and the lowest productivity. Consequently, it will not be taken into account for further discussion as comparative characteristics are low.

5.1. Height growth

Deviations of mean heights in Ukraine comparing to the yield tables are changing from -20,6 to 24,5% (Table. 4.1, Appendix B). Significant fluctuations of deviations of mean heights are caused by the place of plots setting. The produced information testifies that, independently of type of the yield tables, with age advancing mean heights of sample plots converge to tabular data (minimal deviations within investigation equal 0,2%).
The maximal values of deviations are inherent for stands in the age of 60-80. It specifies on a certain features of stands growth in this age, which are predetermined by the internal structure of stands due to absence of silviculture.
Comparison of data from the Swedish sample plots and yield tables testifies that individual stands are exceeding deviation of 40% after the Lorey's height. Long-term observations in Sweden confirm that character of silviculture is one of the main factors that influence stands growth after a height.
A difference between the mean heights of the yield tables of site index I and sample plots UA-5, 8, 10 is statistically reliable, other sample plots have statistically reliable heights only during the time of establishment. The reliable difference is statistically confirmed in analyzable information between the heights of sample plots no UA-2 and 4 at the time of establishment and on sample plot no 3 at the time of second measurement. The main reason of significant difference within analyzed heights is disparity of productivity (site index) of chosen sample plots.
Statistically substantial difference between the Lorey's heights in different age periods and tabular data is found on sample plots SWE-860, 828, 815 and 5033:3, on plot SWE-814 reliable difference is in individual age periods, and only on sample plot SWE-831:2 - difference is not substantial. The heights of sample plot SWE-814 have the lowest values in comparing to other plots; they can even be attributed to the site index B28.

Analyzed dynamics of mean and Lorey's heights testifies that stands have individual peculiarities of growth, which not always are reliably represented in elaborated measurement data.

5.2. Diameter growth

Mean diameters of sample plots are increasing with periodical yield within 0,32 – 0,9 cm but this yield doesn't correlate with age. Deviations of sample plots UA-6, 7 and SWE-815 regarding tabular data do not exceed 7%; sample plots UA-3, SWE-814, 815 and 831:2 have deviations less than 10%. The use of analyzable tables would mainly lead to understating of mean diameters.
Maximal deviations of mean diameters of sample plots UA-10, SWE-860 and 828 regarding other investigated plots and tabular information are defined. On our opinion, it can be explained due to intensive silviculture which has been conducted on these areas (because stands of these plots have the lowest density in comparison with sample plots of the same age period).
Tabular value of Student's criterion on 5% level of meaningfulness for more than 120 measurements equal 1,96. Therefore, it determines that mean diameters of sample plots UA-4, 10, SWE-860 and 828 substantially differ from tabular values within whole period of investigation. Reliable differences are confirmed between the mean diameters of the yield tables and sample plots UA-1, 5, 8, SWE-814, 815, 5033:3 and 831:2. Reliable difference is not confirmed between the compared information of measurement data and mean diameters of sample plots UA- 2, 3, 6, 7, SWE-860 and 828.

5.3. Development of basal area

Materials of sample plots show that investigated beech stands are not characterized by intensive increase of basal area. The biggest change of basal area is observed on the youngest sample plot, and a negative change of basal area is on the oldest plot. Among the reasons of deceleration of increase after a basal area it is opportunely to name differentiation of trees that is predefined by forming spatial structure without anthropogenic interference.
The resulted information testifies that renewal and growth of relative density of beech stands after thinnings is passing off during 5-7 years period. It is necessary to notice that in comparing to other inventory indexes percent of deviations between actual and tabular values after basal area is the lowest. The maximal values of deviations between the investigated data in overwhelming majority do not exceed 30%, except sample plot SWE-831:2. Values of deviations of actual basal areas regarding their appropriate tabular values chiefly do not exceed 10%, especially if to speak about Swedish sample plots.

5.4. Reduction of number of stems per hectare

It is impossible to trace features of density changing from the establishment due to absence of appropriate data. Comparison of the data on the investigated period specifies on the substantial decline of the number of stems before investigation. Decrease of the number of stems on all sample plots is occurring similar to data of the yield tables.
Deviations of number of stems per ha considering yield tables of Beechen forest type and B32 do not exceed 10% up to age of 70. It specifies similar dynamics of decrease of stand density in Ukraine and in Sweden. Further decrease of stand density, which is controlled by silviculture, guarantees creation of desired structure of the stands.

5.5. Development of volume, CAI and MAI of volume

Standing volumes of Ukrainian sample plots show mainly lower values than data of the yield tables. The lower volumes of investigated sample plots can be explained by silviculture, forming of not optimum composition and structure of stands due to absence of adapted regimes of growing highly productive beech stands. Increase of standing volumes is observed on all investigated sample plots and it becomes more intensive after the age of 60. Obviously, the intensive increase of volumes is peculiar for sample plots where interconnection of trees has been set up.

Near to tabular values volumes of Swedish sample plots prove that there is possibility to produce highly productive stands with expedient structure by using proper silviculture.

Differences in volumes of analyzed yield tables are partly stipulated by the reason of using table for mixed stands (Ukrainian yield table for site index I).

Biological particularities of certain tree species, its origin, age, density, soil conditions, sanitary condition of a stand, and accomplished silviculture can influence value of stem increment (Grom 2007).

Pre commercial and commercial thinnings don't have significant influence on growth and development of young beech stands till the age of 50 because values of CAI of volume are similar in both countries. Intensive silviculture in beech stands of Ukraine stipulates decreasing of values of current increments till the age of 120. Systematized approach directed on growing business assortments in Sweden leads to difference in 4 m^3/ha per year at the age of 120 between the Swedish and Ukrainian values of CAI of volume.

Beech stands are characterized by considerable energy of growth in both countries. Pre commercial thinnings in Sweden maintain intensity of volume increment till the final felling. Considering culmination of MAI of volume in the Ukrainian yield tables, final felling can be appointed at the age of 70 but Ukrainian law doesn't give such opportunity. Analysis of beech growth in Sweden shows culmination of MAI of volume at 120 years and mean diameters at that time equal 53 centimeters; therefore sufficiently high output of thick business timber is provided. Such features of growing beech are rationally to recommend in Ukraine.

5.6. Possible factors that stipulated differences concerning growth and deviations

The analyzed data indicate individual features of beech growth. The yield tables must take into account essential factors that influence growth and productivity of a stands (these factors are considering during the choice of stand of one natural row of growth and development). The methodical approaches for the choice of stands are different, that is why measurement data can be built on basis of a site index or typology, for normal, modal or optimal stands, etc.

Among the main reasons that stipulated certain features of growth of the beech stands and their difference from normative information it is possible to name:

- site conditions;
- origin of a stands and their composition;
- different approaches regarding structure forming in young age;
- character of silviculture during the period of growing;
- method of selection of the stands of one natural row of growth and development;
- method of tabulation of the yield tables.

5.7. Comments on the overall results

The mean inventory indices are pointed in the Ukrainian yield tables for the main crop and for yield from thinnings. These indices reflect dynamics of growth in general and don’t allow determination of silviculture regime. Change of basal area is regulated in the Swedish yield tables; therefore it gives possibility to form the structure of a stand during the pre commercial thinnings.

Analysis of deviations of the basic inventory indexes on all sample plots regarding data of the yield tables and estimate of Student’s criterion point at possibility of reliable determining of the inventory indices by using Swedish yield tables and Ukrainian yield tables that are created on the basis of site conditions.

Site conditions and approaches concerning forming and growing in Ukraine and in Sweden do not enable to recommend one of the type of analyzed yield tables for an estimation and prognosis of development of beech stands in both countries.

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APPENDIXES

Appendix A
Table A.1 Characteristics of beech sample plots in Ukraine

Plot No	Year of measurement	Number of stems per ha	Age, years	Diameter, cm	Mean height, m	Lorey's height, m	Basal area	Volume m^3/ha	Site index	Condition
UA-1	1990	194	94	32,5	29,8	30,4	22,7	305	I	
	2008	159	112	43,2	34	34,3	23,6	368	Ia	windbreak
UA-2	1987	369	72	22,1	22,4	23,5	29,0	323	I	
	2008	224	93	30,7	29,3	30,4	33,0	448	I	
UA-3	1985	474	45	15,3	18,6	19,4	19,3	177	I	
	2008	210	68	23,5	23	23,6	20,2	218	I	
UA-4	1991	230	96	43,6	26,4	27,3	29,8	368	I	
	2008	155	113	50,1	30,3	31,5	30,5	458	I	
UA-5	1989	274	59	24,3	25,4	25,7	25,2	320	Ib	
	2008	154	78	32,3	29,9	30,1	25,2	334	Ia	windbreak
UA-6	1989	441	65	23,9	27,9	28,5	27,8	364	Ia	
	2008	311	84	32,1	29,9	30	30,6	404	Ia	windbreak
UA-7	1998	360	66	26	23,8	24,8	23,2	280	Ia	
	2008	320	76	30,2	24,8	25,6	24,1	300	Ia	
UA-8	1997	638	59	29	25,5	27,8	21,0	265	I	
	2008	494	65	30	28	30	22,7	306	Ia	
UA-9	1998	140	163	62,1	30,5	32,5	42,4	597	II	
	2008	127	168	63,6	31,6	33,5	40,3	636	I	
UA-10	1998	259	51	33,4	22,7	25,1	18,5	211	Ia	
	2008	164	61	39,3	24,7	26,2	20,0	233	Ia	

Continuation of Appendix A

Table A.2 Characteristics of beech sample plots in Sweden

Plot No (official)	Year of measurement	Number of stems per ha	Age, years	Diameter, cm	Lorey's height, m	Basal area	Volume, m^3/ha	Site index
SWE-860	1986	528	52	22,7	22,3	21,4	215	Beech-34,1
	1991	388	58	26,3	23,2	21	223	
	1996	320	63	28,2	23,9	20	219	
SWE-828	1981	468	55	23,1	19,4	19,6	168	Beech-30,4
	1990	348	64	27,5	22,8	20,7	211	
	1999	168	73	38,8	24,8	19,9	219	
SWE-814	1977	713	60	19,3	20,2	21	190	Beech-30,2
	1981	683	64	21,6	21,5	24,9	240	
	1987	517	69	23,1	23,9	21,7	231	
	1994	404	77	26,1	24,5	21,7	240	
	2004	333	87	29,2	25,9	22,3	257	
SWE-815	1977	972	55	15,9	19,3	19,4	170	Beech-29,6
	1981	960	59	17,6	20,4	23,3	215	
SWE-5033:3	1990	1971	35	11,2	13,5	19,3	120	Beech-32,7
	1995	1486	40	12,4	14,8	17,9	124	
	2000	1129	46	13,9	17,7	17	144	
	2006	886	52	15,1	19,3	15,8	147	
SWE-831:2	1973	960	55	14,8	17	16,4	128	Beech-30,3
	1978	640	60	16,5	18,9	13,7	117	
	1986	610	67	20,1	21,8	19,3	190	
	1992	410	74	22,9	23,7	16,9	182	

Appendix B

Table B.1 Deviations of heights of sample plots regarding data from the yield tables

Plot No	Age, years	Mean height, m	Lorey's height, m	Deviations regarding tabular data, %		
				Ukrainian		Swedish
				Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-1	94	29,8		0,19	-1,27	
	112	34		1,19	0,35	
UA-2	72	22,4		-2,22	-4,01	
	93	29,3		-0,06	-1,49	
UA-3	45	18,6		3,02	-1,92	
	68	23		-0,92	-3,10	
UA-4	96	26,4		-2,20	-3,28	
	113	30,3		-0,96	-1,62	
UA-5	59	25,4		4,31	0,57	
	78	29,9		5,43	0,25	
UA-6	65	27,9		4,61	1,11	
	84	29,9		1,57	-0,44	
UA-7	66	23,8		0,29	-2,21	
	76	24,8		-0,95	-2,82	
UA-8	59	25,5		4,42	0,65	
	65	28		4,71	1,19	
UA-9	163	30,5		-1,05	1,89	
	168	31,6		-0,17	3,86	
UA-10	51	22,7		5,39	0,56	
	61	24,7		2,81	-0,53	
SWE-860	52		22,3			6,30
	58		23,2			5,07
	63		23,9			6,81
SWE-828	55		19,4			2,62
	64		22,8			2,89
	73		24,8			3,95
SWE-814	60		20,2			2,15
	64		21,5			1,90
	69		23,9			2,75
	77		24,5			1,41
	87		25,9			1,51
SWE-815	55		19,3			3,18
	59		20,4			2,52
SWE-5033:3	35		13,5			11,91
	40		14,8			5,49
	46		17,7			5,54
	52		19,3			7,01
SWE-831:2	55		17			0,27
	60		18,9			0,64
	67		21,8			1,44
	74		23,7			1,72

Continuation of Appendix B

Table B.2 Deviations of mean diameters of sample plots regarding data from the yield tables

Plot No	Age, years	Mean diameter, m	Deviations regarding tabular data, %		
			Ukrainian		Swedish
			Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-1	94	32,5	-8,3	-2,9	
	112	43,2	4,2	15,1	
UA-2	72	22,1	-18,6	-18,7	
	93	30,7	-12,5	-7,6	
UA-3	45	15,3	-1,2	-12,5	
	68	23,5	-7,9	-9,2	
UA-4	96	43,6	20,6	28,3	
	113	50,1	19,9	32,7	
UA-5	59	24,3	11,8	6,6	
	78	32,3	26,6	24,8	
UA-6	65	23,9	-1,6	-3,9	
	84	32,1	0,9	4,2	
UA-7	66	26	5,3	3,1	
	76	30,2	5,1	6,2	
UA-8	59	29	33,4	27,3	
	65	30	23,6	20,6	
UA-9	163	72,1	32	64,6	
	168	75,6	36	71,9	
UA-10	51	33,4	83,3	68,5	
	61	39,3	74	67,3	
SWE-860	52	22,7			53,5
	58	26,3			52
	63	28,2			45,2
SWE-828	55	23,1			44
	64	27,5			38,6
	73	38,8			63,6
SWE-814	60	19,3			6,4
	64	21,6			8,8
	69	23,1			5
	77	26,1			2,5
	87	29,2			-2,2
SWE-815	55	15,9			-0,9
	59	17,6			-0,7
SWE-5033:3	35	11,2			43,4
	40	12,4			26
	46	13,9			13
	52	15,1			2,1
SWE-831:2	55	14,8			-7,7
	60	16,5			-9,1
	67	20,1			-4,9
	74	22,9			-5,2

Appendix C

Table C.1 Estimating reliability of differences between the heights of sample plots and yield tables

Plot No	Age, years	Height, m	The actual values of Student's criterion calculated between the values of sample plots and yield tables		
			Ukrainian		Swedish
			Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-1	94	29,8	0,19	-1,27	
	112	34	1,19	0,35	
UA-2	72	22,4	-2,22	-4,01	
	93	29,3	-0,06	-1,49	
UA-3	45	18,6	3,02	-1,92	
	68	23	-0,92	-3,10	
UA-4	96	26,4	-2,20	-3,28	
	113	30,3	-0,96	-1,62	
UA-5	59	25,4	4,31	0,57	
	78	29,9	5,43	0,25	
UA-6	65	27,9	4,61	1,11	
	84	29,9	1,57	-0,44	
UA-7	66	23,8	0,29	-2,21	
	76	24,8	-0,95	-2,82	
UA-8	59	25,5	4,42	0,65	
	65	28	4,71	1,19	
UA-9	163	30,5	-1,05	1,89	
	168	31,6	-0,17	3,86	
UA-10	51	22,7	5,39	0,56	
	61	24,7	2,81	-0,53	
SWE-860	52	22,3			6,30
	58	23,2			5,07
	63	23,9			6,81
SWE-828	55	19,4			2,62
	64	22,8			2,89
	73	24,8			3,95
SWE-814	60	20,2			2,15
	64	21,5			1,90
	69	23,9			2,75
	77	24,5			1,41
	87	25,9			1,51
SWE-815	55	19,3			3,18
	59	20,4			2,52
SWE-5033:3	35	13,5			11,91
	40	14,8			5,49
	46	17,7			5,54
	52	19,3			7,01
SWE-831:2	55	17			0,27
	60	18,9			0,64
	67	21,8			1,44
	74	23,7			1,72

Continuation of Appendix C

Table C.2 Estimating reliability of differences between the diameters of sample plots and yield tables

Plot No	Age, years	Mean diameter, cm	The actual values of Student's criterion calculated between the values of sample plots and yield tables		
			Ukrainian		Swedish
			Site index I (Dmitriev 1967)	Beechen forest type (Myklush 1986)	B32 (Carbonnier 1971)
UA-1	94	32,5	-0,99	-0,33	
	112	43,2	1,09	3,66	
UA-2	72	22,1	-1,13	-1,15	
	93	30,7	-1,35	-0,77	
UA-3	45	15,3	-0,04	-0,41	
	68	23,5	-0,47	-0,57	
UA-4	96	43,6	4,92	6,39	
	113	50,1	13,48	20,14	
UA-5	59	24,3	0,63	0,36	
	78	32,3	2,23	2,10	
UA-6	65	23,9	-0,10	-0,24	
	84	32,1	0,10	0,42	
UA-7	66	26	0,33	0,20	
	76	30,2	0,45	0,54	
UA-8	59	29	2,09	1,77	
	65	30	1,70	1,52	
UA-9	163	72,1	7,33	11,86	
	168	75,6	6,98	11,03	
UA-10	51	33,4	5,25	4,70	
	61	39,3	7,99	7,56	
SWE-860	52	22,7			2,18
	58	26,3			2,33
	63	28,2			2,44
SWE-828	55	23,1			1,64
	64	27,5			2,07
	73	38,8			6,99
SWE-814	60	19,3			0,24
	64	21,6			0,39
	69	23,1			0,26
	77	26,1			0,16
	87	29,2			-0,19
SWE-815	55	15,9			-0,03
	59	17,6			-0,02
SWE-5033:3	35	11,2			0,57
	40	12,4			0,44
	46	13,9			0,29
	52	15,1			0,06
SWE-831:2	55	14,8			-0,23
	60	16,5			-0,32
	67	20,1			-0,22
	74	22,9			-0,29