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MAIN TYPES OF FOREST STANDS DYNAMICS IN THE UKRAINIAN CARPATHIANS

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Довгострокові дослідження динаміки лісів в Українських Карпатах започатковані Карпатським філіалом УкрНДІЛГА (тепер – Український науково-дослідний інститут гірського лісництва імені П.С. Пастернака) в 1960-х роках. Більш ніж 10 постійних пробних площ на трьох вертикальних профілях були закладені в регіоні співробітниками інституту. Впродовж багатьох десятиліть вони забезпечують фундаментальні результати досліджень для обґрунтування регіональних систем ведення лісового господарства. На даний час ці дослідження є науковою основою для впровадження "наближеного до природи" ведення лісового господарства.

Основні типи природних лісів мають стабільну динаміку в регіоні Українських Карпат за останні 50 років. Проте тенденції їх динаміки різні, а обумовлені вони основними породами, віком та/або породним складом цих деревостанів. Букові деревостани на даний час є найбільш поширеними (більше 50% площі лісів) в регіоні і найбільш агресивними щодо інших порід (дуба, ялини чи ялиці) у всіх типах лісу: чистих бучинах, ялиново-ялицево-букових, буково-дубових. А буковий праліс Українських Карпат – це природна ілюстрація найбільш стійкого деревостану у відповідних типах лісу з циклічними змінами таксаційних показників за стадіями розвитку, з запасом мертвої лежачої деревини на рівні 8-ми річних приростів (≈100 м^3/га), з достатньою кількістю природного відновлення (на рівні 25 тис. шт./га) та з необмеженим (≈500 років) віковим циклом. Суттєвий вплив на динаміку букових пралісів мають тільки природні чинники, а особливо – сильний вітер (на деревостан) та дикі тварини (на природне відновлення).

Найбільш стійкими деревостанами в регіоні є чисті яличники (10% площі лісів) і ялиця біла, як і бук, має тенденцію розширювати свій ареал практично на всі типи лісу Українських Карпат через її успішне природне відновлення (до 30 тис. шт./га). Відмітимо в яличниках максимальні в регіоні запаси деревини (≈800 м^3/га) та максимальну поточну зміну її запасу (до 15 м^3/га/рік). Чисті ялинники (10% площі лісів) мають не чітку тенденцію до погіршення стану, яка ясно проявляється (до 30% всихання за запасом) в змішаних ялицево-буково-ялинових деревостанах (20% площі лісів). Це погіршення стану ялини прив'язане в першу чергу до складних лісорослинних умов. Погіршення регіональних дібров (10% площі лісів) є чітким через їх значний вік та інтенсивний ріст нижнього грабового ярусу.

Вплив глобальних змін клімату також є суттєвим для природних лісів Українських Карпат – одним з його наслідків є поява нових видів у підрості. Наприклад, дуб скельний і черешня – у буковому пралісі та бук лісовий і ялиця біла – в чистому ялиновому деревостані. Іншим наслідком є суттєві зміни в породному складі (зміна головної породи) лісів регіону – бук та

ялиця масово (на 20% площі лісів) витісняють ялину.
Всихання похідних ялинників в Українських Карпатах є великою лісівничою проблемою в зв'язку з масовим поширенням цього явища в регіональному масштабі і тому, що нові змішані ліси (що з'явилися на місці ялинників, які всохли) не дають таку цінну деревину так швидко – втрати за типами лісу коливаються від 20 до 40 років.
Ключові слова: ліси Українських Карпат, довгострокова динаміка, бук лісовий, ялина європейська, дуб черешчатий, ялиця біла, похідні деревостани

Shparyk Y.S., Berkela Y.Y., Viter R.M., Losiuk V.P. **Main types of forest stands dynamics in the Ukrainian Carpathians**
Long-term investigations of the forest dynamics in the Ukrainian Carpathians was started by Ukrainian Research Institute for Mountain Forestry back in 1960-s. More than 10 permanent plots within three vertical profiles were laid in the region by its collaborators. During many decades, they provide some basic research results for the regional sylvicultural systems, and now – for the close-to-nature forestry implementation.
Main types of natural forest stands have stable dynamics in the Ukrainian Carpathians during this time. However, the trends of their dynamics are different and are driven by these stands' main species and/or species composition. Common beech stands are most aggressive in their development practically in all types of regional forests: pure beech, spruce-fir-beech, beech-oak. Dynamics of the regional beech virgin forests are cyclic and its trend driven by a development stage of the virgin forest massive. Pure Silver fir stands are most stable for the regional forests and this species has a trend to expand its presence too. Pure Norway spruce stands have a not clear trend to deterioration, which is clear in the mixed fir-beech-spruce forests. Deterioration of the regional Pedunculate oak forests is clear in consequence of their old age and a lower hornbeam layer growth-up.
Effects of the global climate change are also substantive for natural forests – appearance of new species in their undergrowth is one of them. For example, Sessile oak and Wild cherry – in the beech virgin forest; Common beech and Silver fir – in the pure spruce forest.
Decline of the secondary spruce forests in the Ukrainian Carpathians is a big forestry problem due to its regional scale and because new mixed forests (that appeared in their area) have not so valuable timber.
Key words: Ukrainian Carpathian forests, long-term dynamics, Common beech, Norway spruce, Pedunculate oak, Silver fir, secondary stands

Long-term investigations of the forest dynamics provide results of basic forestry research for understanding of forest stand changes and for optimal forestry actions planning (Pohrebnyak, 1968; Korpel, 1995; Oliver, Larson, 1996; Schütz, 2001; Waring, Running, 2007; Myagchenko, 2010; Shparyk, 2016). There is a special chapter in the Ukrainian forestry science – Changes of Species in the Forest. And these results are especially crucial in the context of "close-to-nature forestry" – very popular modern sylvicultural system, as implementation of sustainable forest management (O'Hara, 2014; Kirby, Watkins, 2015; Krynytskyi et al, 2017).

Ukrainian Carpathians' forests have mainly good natural regenerations what is first step to close-to-nature forestry (Gerushynskyj, 1996; Gensiruk, 2002; Shparyk, 2016; Krynytskyi et al, 2017). According to the forest inventory data the largest forest areas in the region have Norway spruce (*Picea abies* (L.) H. Karst) and Common beech (*Fagus sylvatica* L.) forests. There are two main parts of the regional forests: north-eastern macro slope (Prycarpattya), where dark coniferous species dominate – Norway spruce and Silver fir (*Abies alba* Mill.); south-western macro slope (Zacarpattya), where hardwoods species dominate – Pedunculate oak (*Quercus robur* L.) and Common beech. The actual upper timberline is mainly formed by two forest stands: pure Norway spruce and pure Common beech. Sometimes it is formed by mixed fir-beech-spruce, Sycamore (*Acer pseudoplatanus* L.) – beech and Cedar pine (*Pinus cembra* L.) – spruce forest stands.

Forest type is very important for the regional forestry because there are many dominant species here. The forest types of the Ukrainian Carpathians vary highly, due to the diversity of landscape conditions. There sites with the following basic forest formations (groups of forest types) in the region: Pedunculate oak forest types – on the Precarpathian lowland; Sessile oak (*Quercus petraea* (Matt.) Liebl.) forest types – on the Transcarpathian lowland; Fir-beech-spruce forest types – on the Precarpathian lower mountain land; Sessile oak-beech forest types – on the Transcarpathian lower mountain land; pure Norway spruce forest types – on the Precarpathian higher mountain land; pure Common beech forest types – on the Transcarpathian higher mountain land. Pure Mountain pine (*Pinus mugo Turra*) forest types are usually located in subalpine zone. There are Green alder (*Alnus viridis* L.) and Carpathian rhododendron (*Rhododendron myrtifolium* Schott & Kotschy) forest types on the rocky steep slopes in alpine zone (Gerushynskyj, 1996; Gensiruk, 2002; Shparyk, 2016).

The area of the Ukrainian Carpathians' forests has been increasing during last 60 years and it has a trend to stabilization for last 20 years. Norway spruce forests were dominating in the region for many years, but their area became less than area of the regional beech forests in 1996 due to forestry activities and climate conditions changing. The area of non-managed forests in the region has most clear trend to increase during last 60 years, and the intensity of its increasing is very high – from 400 to 1100 thousand ha. Wood volume is highly increasing too (from 310 to 640 million m^3) but mainly after 1978. Area of mature stands in the region had maximum values in the middle 1950s, and then it began to decline, and since 1978 has again tended to increase. The dynamics of the young stands' area is opposite. This is evidence that the Carpathian forests are aging, as well as that there is a trend of timber volume increment per hectare – it has increased from 2.1 to 5.4 m^3/ha/year for the last 65 years (Shparyk, 2016). There are some types (beech, spruce, mixed) of a virgin forest in the Ukrainian Carpathians and different scientists give a lot of attention to them in last decades (Shparyk et al., 2017).

The main forestry problems in the region are as follows: progressive aging of not managed forests and their health condition deterioration; intensive reduce of managed forests' area; progressive increasing of wood volume; much more (twice) area of Silver fir forest types than area of its forest stands; intensive reducing of Norway spruce forest stands areas; only one Common beech and many Norway spruce forestry management sections; large areas of forests with too small basal area (Shparyk, 2016).

Objects and methods

Forest stands dynamics has been investigated from 1965 on the permanent plots of the Ukrainian Research Institute for Mountain Forestry in the main types of regional forest stands. For example, 10-ha permanent plot in the beech virgin forest was set up in 2000 (compartment 2 of the Uholka division in the Carpathian Biosphere Reserve). 1-ha permanent plot in the natural spruce forest was set up in 1965 close to the highest peak of the Ukrainian Carpathians (m. Hoverla). 1-ha permanent plot in the natural oak forest was set up in 1967 close to a border of the Ukrainian Carpathians (t. Kolomyia). 1-ha permanent plot in the natural fir forest was set up in 1966 in the forest reserve Klyva close to Deliatyn. 1-ha permanent plot in the secondary spruce forest was set up in 1998 in the National natural park Hutsulshchyna close to Kosiv in the wet mesotrophic spruce-fir-beech forest type.

All trees ≥ 6 cm DBH mapped and measured (state, DBH, height of control trees, crown height of control trees, IUFRO classes, remarks) on these plots within species. The lying deadwood assessed within 4 degrees of decay by measuring the length and mean diameter of all parts with a minimum length of 2 m and a minimum diameter of 8 cm. The natural regeneration was counted within height groups (10-30, 30-50, 50-70, 70-90, 90-130, >130 cm) on 20 m^2 circular plots and more than 10% of plot area. The inventories completed according

to the methodological recommendations of the International Union of Forest Research Organizations (IUFRO) and in line with Ukrainian methodologies.

Results

Uholka primeval beech stand is uneven-aged and multi (3-5) layered and its taxation parameters are strong varied. It is almost pure (95% of trees' volume) beech forest with large mean dimensions (diameter – 43.8 cm, height – 36.3 m), high number of trees as for so big trees (300-500 per ha) and a rather low standing volume (630 m^3/ha). Nevertheless, a mean deadwood volume is high – over 70 m^3/ha, as well as a tree crown surface – almost 50 m^2 and natural regeneration density – over 20 000 per ha. Dynamics of the virgin forest parameters within 2000-2015 are different and for their variability decreasing are as follows: percent of beech in the species composition was most stable – 95.6±0.10%; stand basal area (G) was stable too – 38.6±0.41 m^2/ha; DBH was decreasing – 39.5±2.17 cm; number of natural regeneration (NR) had a small variability with a trend to decreasing – 26.0±1.99 ths./ha; stand volume (V) had a small variability with not clear trend – 598.2±11.29 m^3/ha; dead wood volume (DW_V) had a middle variability with clear trend to increasing – 113.6±17.40 m^3/ha; number of trees (N) had big variability with trend to increasing – 325.0±40.35 ha^{-1} (fig. 1, 2).

Natural Norway spruce forests are almost uneven-aged and mainly two layered. Their taxation parameters had no big variation – maximum for the tree number was 15%. Their stand was pure (99% of trees' volume) spruce forest with large mean dimensions (diameter – 42.3 cm, height – 28.8 m), not high number of trees (300-400 per ha), a rather high standing volume (665 m^3/ha), low deadwood volume (10 m^3/ha), and low natural regeneration density – close to 2 000 per ha. Dynamics of the spruce forest parameters are different too and for their variability decreasing are as follows: stand basal area was most stable – 46.8±0.93 m^2/ha; DBH had a small variability with a trend to decreasing – 42.3±2.05 cm; increment was stable with a small variability – 9.5±1.07 m^3/ha/year; number of natural regeneration had not clear trend to increasing – 2.0±0.89 ths./ha; stand volume had not clear trend to increasing – 665.2±25.45 m^3/ha; dead wood volume had a middle variability without clear trend– 9.5±4.34 m^3/ha; number of trees had a middle variability and decreasing trend – 366.3±36.89 ha^{-1} (fig. 3).

Natural Pedunculate oak forests are almost even-aged and mainly two layered. Their taxation parameters had no big variation. Their stand was complete by two different layers: first (upper) layer was pure (100% of trees' volume) oak stand with large diameter (70 cm), and low number of trees (40-100 per ha, basal area (25 m^2/ha), standing volume (350 m^3/ha); second – almost pure (96%) hornbeam stand with low, but – increasing, all parameters. Dead wood and natural regeneration were practically absent on the plot during this time. Dynamics of the oak stand parameters were in general

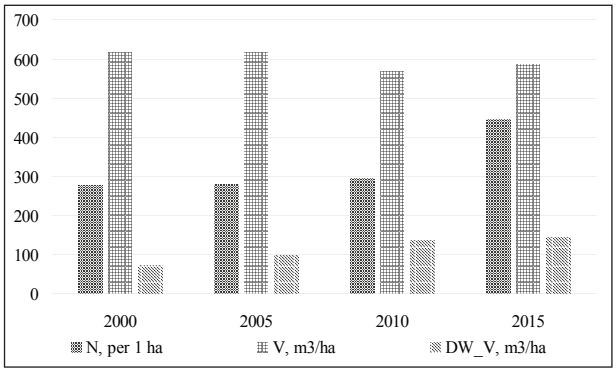

Fig. 1. Number of trees and wood volume of the beech virgin forest

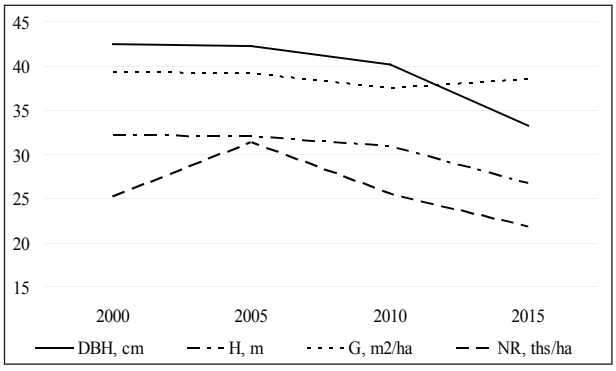

Fig. 2. Other parameters of the beech virgin forest within 2000–2015

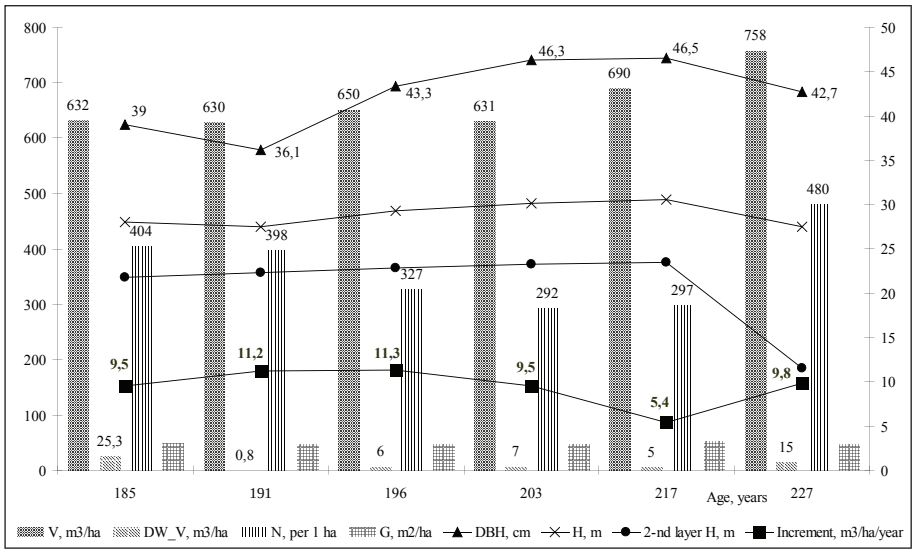

Fig. 3. Dynamics of the natural Norway spruce forest parameters

similar – decreasing all time (fig. 4) and for their variability decreasing were as follows: stand basal area was decreasing from 29.6 to 19.6 m^2/ha (v=1%); number of trees – from 100 to 36 ha^{-1} (v=11%); stand volume – from 400 to 270 m^3/ha (v=12%); only tree height was stable – 30.3±0.19 m; and DBH was increasing – from 60.8 to 79.5 cm (v=1%). Dynamics of the linden-hornbeam stand parameters were opposite: stand volume was increasing from 47 to 220 m^3/ha (v=31%); tree height – from 10 to 22 m (v=2%).

Natural Silver fir forests are uneven-aged and multi (4) layered. Taxation parameters of the plot stand had no big variation – less than 5%, and only for the tree number, it was big (31%). This stand was mix spruce-fir but a fir part in the species composition had a clear trend to increasing from 87 to 99%. Natural fir forest usually had no big dimensions (diameter – 38.3 cm, height – 30.7 m) and deadwood volume (8 m^3/ha), but its number of trees (300-650 per ha) and standing volume (755 m^3/ha) were high. Natural regeneration had big density all time – close to 15 ths. per ha. Dynamics of the fir forest parameters were different too and for their variability decreasing were as follows: stand basal area was most stable – 52.4±1.10 m^2/ha (v<0.1 %); DBH had a small variability with a trend to increasing – 38.3±1.83 cm (v<0.4 %); stand volume had small cyclic changes – 754.7±18.21 m^3/ha (v=2%); dead wood volume was low without clear trend – 7.8±2.12 m^3/ha (v=2%); number of natural regeneration had not clear trend to increasing – 2.0±0.89 ths./ha (v=5%); number of trees had a high variability (v=31%) with cyclic changes – 475.3±60.26 ha^{-1} (fig. 5).

Secondary spruce stands usually were even-aged and had a one tree layer only. Taxation parameters of these stands had a big variation depending on the forest type. For example in the wet mesotrophic spruce-fir-beech forest type (our plot), secondary spruce forest was destroyed during last 12 years. It was thanks global climate changes – there are 2 or 3 weeks

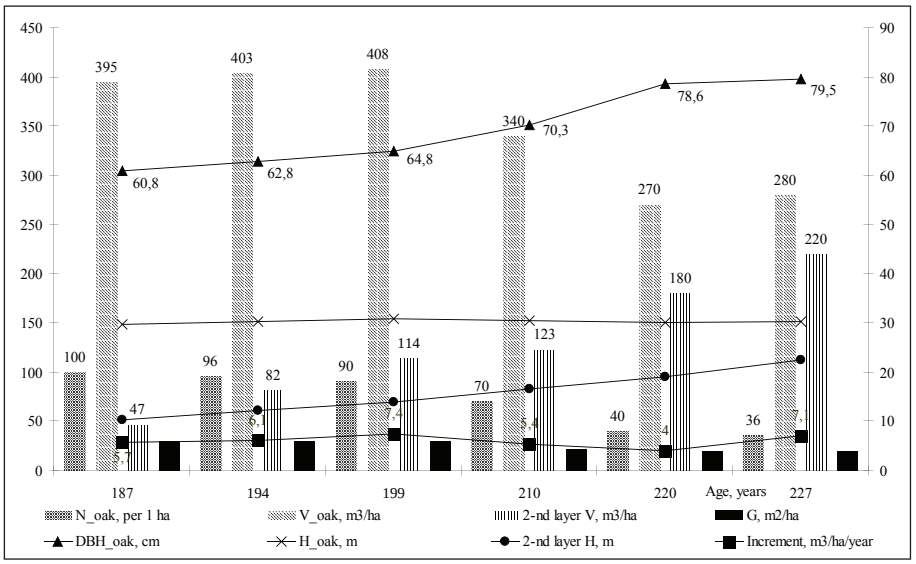

Fig. 4. Dynamics of the natural Pedunculate oak forest parameters

without rain here every season last 15 years. Dynamics of our plot parameters were in general decreasing last 12 years: DBH had a small variability without clear trend – 22.4±2.69 cm (v=1.3%); stand basal area had a clear trend to decreasing – from 31.0 to 14.2 m^2/ha (v=3%); spruce part in the species composition – from 96 to 45% (v=7%); stand volume – from 290 to 70 m^3/ha (v=78%); number of trees – from 520 to 160 ha^{-1} (v=82%). Dynamics of dead wood volume (from 5 to 160 m^3/ha) and natural regeneration (from 0 to 9 ths./ha) were opposite in this time (fig. 6).

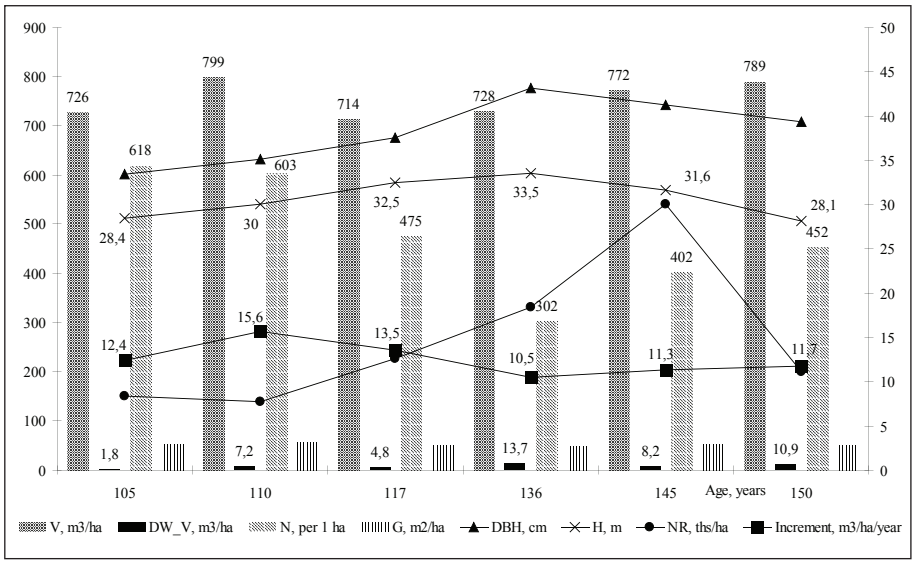

Fig. 5. Dynamics of the natural Silver fir forest parameters

Discussion

Research results from the permanent plots gave a reason to affirm an essential difference in development stages (successions) of main regional forest stands and gave their quantitative indicators. Differences are in their species compositions, lifetime, sizes, vertical and horizontal structures, and in their dynamics directions. This situation is to complicate for their comparison and analyse but a knowledge and understanding of the dynamics trend for each forest compartment (main species) are bases for good forestry results right here. Therefore, long-term investigations of the Ukrainian Carpathians' forests dynamics confirmed classical principles of Forestry (Pogrebnyak, 1968; Gensiruk, 2002):

Natural forest stands are stable for a very long time (more than life of one tree) and their dynamics depends (is determined by) on main species, site and climate conditions;

Secondary forest stands are stable during small period (less than a life of one tree) and their dynamics has two main stages: first – quick growth, second – quick destroying.

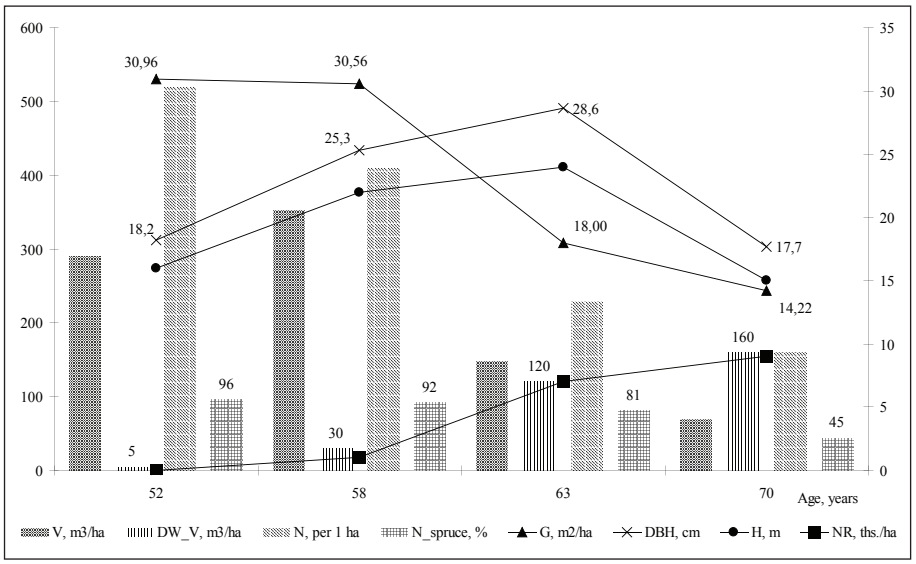

Fig. 6. Dynamics of the secondary Norway spruce forest parameters

For example, beech virgin forest of the Ukrainian Carpathians is a natural illustration of most stable forest stand in the appropriated site conditions with cyclic changes in stand, dead-wood volume, natural regeneration, and unlimited (!?) lifetime. Big number of trees (first of

all – thin trees) is a guarantee of their stability (Korpel, 1995; Schütz, 2001). Strongest effects on beech virgin forests' dynamics have factors of a nature, especially strong wind (on their stand) and wild animals (on their natural regeneration). New species appeared in the beech virgin forest during last 5 (3 species – Sessile oak, Mountain ash, and Willow) and 10 (4 species – previous + Wild cherry) years. In our opinion, natural regeneration of these new species became possible thanks global changes of climate.

Spruce forests of the Ukrainian Carpathians are more transformed than regional beech forests and because their structure is not so complicate especially for secondary stands. Dynamics of the natural spruce forest is stable with some not clear cyclic changes (in DBH and tree number). New species also appeared in the natural spruce forest during last 5 (Common beech) and 10 (Common beech + Silver fir) years. Dynamics of the secondary spruce forests had a clear trend to decline (change on the beech). Rate of their declining depending on the forest type (site and climate conditions). Three stages of these stands decline were identify according to dendrochronological data: initial (from 5 to 10 years in different forest types), intensive declining (10-20 years), and species changing (10-20 years). This secondary spruce forests' decline predetermines a loss more than half of the regional spruce forests in the next 20-30 years. We will have mixed spruce-fir-beech forests on these areas.

Pedunculate oak forests of the Ukrainian Carpathians' region are mainly artificial (planted) with one-layer structure. Some areas of natural (hornbeam-) oak forests have two-layer structure with very different parameters. Dynamics of the natural hornbeam-oak forests point to species composition change from oak to hornbeam due to bad health conditions of oak and due to absence of the oak natural regeneration. Therefore, a natural regeneration of oak forests in the region is possible only theoretically if a management forestry system for these forests has been change.

Silver fir forests of the Ukrainian Carpathians are very rare unlike mixed spruce-fir-beech forests. Pure fir forests have a high stability only in some site conditions (gley soil) like within our permanent plot. Dynamics of the natural fir forest is stable with cyclic changes in DBH, tree number and natural regeneration number. Main change was a loss of spruce in the stand species composition during last 14 years. Nevertheless, spruce part in the natural regeneration is close to 10%. Mark the maximum wood volume and wood volume increment in such forests between main regional forest stands.

Conclusions

Main types of natural forest stands have a stable dynamics in the Ukrainian Carpathians during last 50 years. However, trends of their dynamics driven by these stands' main species and/or species composition. Common beech stands are most aggressive in their development practically in all types of regional forests: pure beech, spruce-fir-beech, beech-oak. Part of beech is increasing in their species compositions and a presence of beech has broaden on the new forest areas. Dynamics of the regional beech virgin forests are cyclic and its trend driven by a development stage of the virgin forest massive. Pure Silver fir stands are most stable regional forests and this species has a trend to expand its presence too. Pure Norway spruce stands have a not clear trend to deterioration, which is clear in the mixed fir-beech-spruce forests. Deterioration of the regional Pedunculate oak forests is clear in consequence of their big age and a lower hornbeam layer growth-up.

Appearance of new species in the undergrowth of natural regional forests is a result of global climate changes. For example, Sessile oak and Wild cherry – in the beech virgin forest; Common beech and Silver fir – in the pure spruce forest.

Decline of the secondary spruce forests in the Ukrainian Carpathians is a big forestry problem because new mixed forests (what appeared in their area) have no so valuable wood.

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