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SOME RECENT RESULTS OF LONG-TERM INVESTIGATIONS IN THE PERMANENT SAMPLE PLOTS OF UKRAINIAN RESEARCH INSTITUTE OF FORESTRY AND FOREST MELIORATION

The aim of this study is to characterize the long-term researches in permanent plots by researchers of institute and the ways of use the new results.

Data from scientific publications of institute researchers are the source of this paper. The brief history of stationary researches of URIFFM is highlighted. Its research network includes now two Branches, six Research Stations and one Department. Attention is paid to content and recent results of long-term investigations in the permanent sample plots of URIFFM and its Research network on issues of forestry, forest breeding, monitoring and protection. It was stated, that the sense of long-term stationary researches is in the regularly repeated assessment of the same parameters by the same methods in the network of permanent sample plots. Parameters of soil, condition of plants and animals (including insects) as well as disturbances frequency and severity are registered simultaneously. It was stated, that succession of generations of scientists is characteristics for long-term researches. Recent results for experiments on thinning started by B. I. Gavrylov in 1932, provenance tests started under guidance of V. D. Ogievsky at the beginning of the XX century and of I. M. . Patlaj in the 70-ties of the XX century are highlighted. The summary on other kinds of forest breeding objects, particularly gene reserves, plus stands and plus trees, progeny tests, clonal and seed plantations is presented. Peculiarities of researches on the Ist and IInd Levels monitoring, as well as local monitoring of forest condition under action of recreation, fire or insect damage are presented. Disadvantages of organization of stationary researches are described, which are connected with lack of funds for regular site visits, and inability to equip the permanent plots with modern instrumentation.

Key words: *forest science, long-term researches, permanent sample plots, forestry; forest protection, forest breeding, forest monitoring.*

Introduction. A tree grows for decades, and forest ecosystems exist for hundreds years. Therefore, the reaction of the trees, and all the more so forest ecosystems on any natural or anthropogenic factors can manifest itself through the years, or even decades. To understand the mechanisms of action of different factors, phenomena or processes on forest ecosystems, the reaction of these ecosystems for prediction the consequences and for making

management decision it is necessary to obtain the information both about certain parameters of ecosystems and affecting factors.

Such information can be obtained by methods of palynology, paleoecology, dendrochronology, simulation, as well as by direct long-term observations in permanent plots (Acker et al., 1998).

The essence of the research in the permanent sample plots (stationary research) consists in systematic repeated assessment of the same parameters in the same plots be the same methods. On the one hand, there are ecosystem parameters, which characterize soil, plants or animals, and on the other hand, there are parameters, which characterize disturbance frequency and severity (Bakker et al., 1996).

Stationary research may be of different duration and to be performed using visual assessment or using complex devices. It is on this principle the programs of forest monitoring and inventory are based in many countries which consist in regularly observation, assessment, evaluation and prediction of dynamics for quantitative and qualitative parameters of forest condition, recognizing the change in spread and dynamics of forest condition (Manual ..., 2010).

Long-term observations on permanent plots give the possibility:

– to investigate natural dynamics of forest communities, populations of forest plants and animals, their interaction, age population dynamics, fruiting dynamics of forest plants in connection with dynamics, frequency and severity of natural and anthropogenic factors;

– to monitor the condition of trees and stands, to determine the most sensitive response characteristics of trees on the effect of various factors;

– to confirm the inheritance the traits of forest species offspring in different age in breeding objects;

– to assess the feasibility of establishing stands with certain species composition or density in the man-made landscapes, the afforestation of non-forest lands, sands and so on;

– to take into account the diversity of environmental conditions in different climatic zones and forest site conditions that determine differences in the course of natural processes influenced by climate change, natural disasters, injurious insects, forest diseases, anthropogenic action (recreation, forest management, technogenic pollution, including radioactive pollution) and to define the strategy of forest growing and protection, which is directed on mitigation the negative effects;

– to substantiate scientifically the measures for cultivation the forest stands with specific target parameters (Tkach and Meshkova, 2015).

Long-term observations on permanent plots provide research succession for scientists of different generations. The scientists of Ukrainian Research Institute of Forestry and Forest Melioration (URIFFM) named after G. M. Vysotsky are guided by such principles during all 85 years of activity of the Institute (UkrNDILHA — 85 rokiv, 2015).

The aim of this study is to characterize the long-term researches in permanent plots by researchers of URIFFM and the ways of use the new results.

Materials and methods. Scientific publications of URIFFM researchers are the source of this paper.

Results. A bit of History. Ukrainian Research Institute of Forestry & Forest Melioration (URIFFM) was founded in 1929 on the base of Bureau of Forestry Research, which was headed by G. M. Vysotsky. This Bureau has inherited the traditions of well-known forester W.E. Graff, who started to grow forest in Velyko-Anadol' in the middle of the 19th century and was the pioneer of steppe forest management. It has inherited also the traditions of V. V. Dokuchayev, who was the chief of Special Expedition, where G. M. Vysotsky was the Head of Velyko-Anadol' division. This expedition has planted 45 forest shelter belts in the Steppe. The measures on soil protection by these stands were developed. Natural factors' influence on forest were investigated, forest shelter belts of blown construction were recommended, the types of water regime and soil hydrology was grounded by G. M. Vysotsky (UkrNDILHA, 2005; UkrNDILHA — 85 rokiv, 2015).

At the date of URIFFM creation, the Bureau of Forestry Research consisted of six experimental forestries, which became the base of new Institute. Mariupolske Research forestry was found in 1843, Volodymyrivske Research forestry was found in 1875, Prydesnyanska station was founded in 1922, Veselobokovenkivsky base and Krasnotrostyanetska station were founded in 1923, and Oleshkivska station was found in 1927.

After multiple reorganizations in 1956, eleven research stations were included into network of URIFFM. There were Volodymyrivska Ameliorative Research Station, Derkulska, Krasnotrostyanetska, Zakarpatska, Mariupolska Forest Research Stations, Prydesnyanskyy base to Control Soil Erosion, Dendrological Park „Veseli Bokovenky", Crimean Mountain & Forest Research Station, Poliska Ameliorative Research Station, Nyzhnyodniprovska Research Station on Sand Afforestation together with Ukrainian Research Station of Viticulture and Forest on Sands Development, as well as Partyzansky Base.

The network of URIFFM gives the possibility to carry out simultaneous researches in different natural zones of Ukraine by the same methods. Now it includes two branches (Stepovy branch named after V. M. Vynogradov and Polisky branch), six research stations (Vinnytska, Kyivska, Luhanska, Mariupolska, Novhorod-Siverska and Kharkivska) as well as Krasnotrostyanetske department (UkrNDILHA — 85 rokiv, 2015).

Now over 80 % of researches of the Institute are carried out in over 600 permanent plots of experimental network of Research Stations (Tkach and Meshkova, 2015). Such researches give the possibility to reveal geographical peculiarities of forest ecosystems' response to environmental influence and forest management, to ground scientific conclusions and to develop respective recommendations considering region and forest site conditions.

History, issues of research and achievements of URIFFM were already presented in many publications (UkrNDILHA, 2005; Meshkova, 2014; UkrNDILHA — 85 rokiv, 2015).

Here we would like to show only recent results.

Recent results. During forest development the rate of growth, response to different environmental and anthropogenic action changes. It brings to trees differentiation, changes of tree species composition and stand productivity and stability. Therefore development of the same forest stand must be studied by several generations of scientists.

The example of continuity in forest research are the experiments, which were started by Prof. B. I. Gavrylov in 1932 in the pine plantations of 7 years old in Balakliyske forestry (subplot 20, plot 57) of the State Enterprise „Balakleysky Forest Economy" in the left bank of Siversky Donets river. The aim of experiments was to estimate the optimal thinning intensity. In the 11 sections several variants of thinning were executed. Prof. B. I. Gavrylov named these stands as plantations of „moderate", „accelerated", „speed" growth and „free" growth.

In the 60th of the last century A. D. Dudarev, in the 70th — O. P. Ryabokon, in the 80th — M. Yu. Popkov and I. B. Shinkarenko, and the last 15 years O. M. Tarnopilska carried out researches in these experimental plots (Tarnopilska, 2012).

O. M. Tarnopilska has analyzed dynamics of crown parameters, canopy, growth parameters and ground vegetation in relation with growing regimes (Tarnopilska, 2012, 2014).

In each enterprise of experimental network of URIFFM experiments have started for development the systems of forest management on the base of typology, theory and practice of thinning and final felling, target forest growing (Tkach and Meshkova, 2015). Natural regeneration is studied after reconstructive felling under guidance of Corresponding Member of NAAS of Ukraine Prof. V. P. Tkach (Tkach, 2015 ab). Obtained results gave the possibility to complete the recommendations on thinning in artificial pine stands depending on forest site conditions, to make precise the ranges of thinning intensity, to suggest the regimes of artificial pine stands growing.

In the forests of Chernobyl accident zone for over 30 years regularities of radionuclides' migration in soil, vegetation, timber, mushrooms and animals are studied. It gave the possibility to develop the recommendations on forest management under radioactive contamination. After such long decomposition and migration of radionuclides in different components of forest ecosystem some types of forest production are no more dangerous and can be used in forest management, that are some standards can be renewed (Krasnov et al., 2015).

Stationary researches in different geographical zones include the objects which differ by type and intensity of certain disturbances (thinning, felling, fires, technogenic pollution, recreation, insect pests' outbreaks, epiphytoties etc).

Provenance tests are important type of stationary objects. They are the stands created using planting material of different geographical origin in uniform ecological conditions or of the same origin in different geographical regions.

The bright example of continuity there are the researches in geographical plantations of Scots pine (Pinus sylvestris L.), being planted at the beginning

of XX century by initiative of V. D. Ogievsky in 21 forest economies in the territory of European part of Russia, including Sobitske forest economy of the State Enterprise „Shostkynsky Forest Enterprise". In these objects many generations of researchers worked. It was S. A. Samofal in the 20-th of the last century, A. A. Krasyuk — in 1941, A. V. Patranin in 1950, G. P. Sannikov and V. G. Daniltseva in 1954 — 1955, G. M. Gordienko in 1961, I. M. Patlaj in 1962—1963, L. I. Tereshchenko and V. P. Samodaj since 90th of the last century up to now (Tereshchenko, Samoday, and Moroz, 2008). These investigations gave the possibility to differentiate pine climatypes in the territory of former USSR and Ukraine, to create the schemes of zoning for possible seed transmission.

Researches in provenance tests show, that the provenances from the eastern and south-eastern parts of range and from mountain localities demand less amount of heat for budburst and flush earlier than native provenances. Provenances from the western part of range and lowlands with often late frosts demand greater amount of heat and flush later. If we carry planting material to the regions to the regions, where they flush or flower earlier (in concordance with thermal demands) than local provenances, such plants can be damaged by late spring frost, which brings to increment losses and stem shape worsening. The plants, which late complete vegetation, can be damaged by early autumn frost; their shoots have not time to lignify. In another cases of discrepancies for plants' thermal demands and ecological conditions additional waves of autumn increment or flowering can weaken the plants. If climate change would be unfavorable for local forest tree species, it would be necessary to find some introducers considering their thermal demands and demands to the terms of vegetation beginning and completing.

Another peculiarities of climatypes there are the dates of start of vegetation and its duration, growth rate, fruiting intensity, resistance to damage by some pests and pathogens, which is connected with violation of synchrony for tree and pest phenology. Except researches of mechanisms of heritability and resistance, investigations in provenance tests give the possibility to simulate the consequences of climate change for forest tree species.

The example of such investigations is the network of provenance tests of Scots pine, European oak (*Quercus robur* L.) and ash (*Fraxinus excelsior* L.) (Los et al., 2014; UkrNDILHA — 85 rokiv, 2015).

In 1976—1977 the network of oak provenances was created in Transcar¬pathians, Vinnitsa, Sumy and Luhansk regions under guidance of I. M. Patlaj, where provenances from different parts of European part of oak range (Bilorys, Central Chernozem Region and Volga region of Russia, Polissya, Forest Steppe and Steppe zone of Ukraine, Crimea etc. were represented (Hayda, 1989; Los, 2008).

V. P. Samodaj was the first in Ukraine who investigated intraspecific variability of Scots pine in provenance tests of the IIIrd generation and European oak of the IInd generation in provenance tests of Sumske Polissya and northern part of the Left bank Forest Steppe of Ukraine (Samoday, 2008).

It gave the possibility to correct the statement on regionalized movement of seed material. The perspective regions of seed collecting were recommended to grow stable, productive, resistant stands in these regions.

Provenance tests of European ash were created in 1930 under guidance of Prof. V.M. Andrejev in the State Enterprise „Trostyanets Forest Economy" (Forest Steppe part of Sumy region). In the frame of these plantations five provenances of ash were analyzed: Polisky, Zakhidny Lisostepovy, Right-bank Lisostepovy, Left-bank Lisostepovy and Stepovy. T. L. Kuznetsova (Kuznetszova, 2009) has analyzed intraspecific variability of ash in ecological& geographical provenance tests, started in the territory of Trostyanets Forest Research Station in 1930 in fresh oak stands (Left-bank Forest Steppe of Ukraine). The best growth and productivity were estimated for ash progenies of Right-bank Lisostepovy provenance.

It was revealed (Davydenko et al., 2013), that the highest spread and severity of ash dieback, caused by invasive pathogen Hymenoscyphus pseudoalbidus, were characteristics for Stepovy provenance.

On the background of climate change, tree species assortment is under interest, which can be introduced into stands with minimal risk of productivity decrease and negative influence on gene pool of native tree species. Research was devoted to development of complex estimation of success of Picea Dietr. introduction. Perspective of the use of these species in the stands of different targets was proved for the East of Ukraine (Sumy, Kharkiv and Donetsk regions) (Vysotska, 2010).

Provenance tests are only one type of forest breeding objects. In general breeding objects are created with the aim of improvement and expansion of forest seed base, to study the mechanisms of introducers' adaptation, to research the structure and condition of gene pools of tree species, level of gene variability, gene dependency and heredity of quantitative and qualitative features, gene flow and exchange in intraspecific and interspecific levels. The important types of stationary forest breeding objects there are the forest gene conservation, seed growing and tree improvement objects (gene reserves, plus stands, plus trees, provenance tests, progeny tests, clonal archive, seedling and clonal seed orchards and experimental plantations of exotic species etc.). Over 500 gene reserves, 3 thousands of hectares of plus-stands and over 4 thousands of plus trees of 30 tree species were selected; about 1400 ha of clonal plantations and 100 ha — of family forest seed plantations have been created. Over 3 thousands of progenies of plus trees are tested in progeny tests. The investigation on these units were directed to conservation of genetic diversity and research on the forest tree species variability on species, population and individual level; study of the structure and condition of natural forest trees populations and their heredity properties; the development of strategies on the in situ conservation of genepool of forest species; the development of recommendations on the renewal of existing units of conservation that are at final stages of succession (Los et al., 2014). Variability of plus trees by growth, reproduction, phenology and development were studied in these objects (Tereshchenko, 2006; Los et al., 2015).

So research the clones of plus trees of Scots pine and their progenies (F1, F2) by biometric, phenological, reproductive characteristics show the possibility of early indication of growth rate for Scots pine, as well as possibility of identification and selection for crossing the trees by cytological peculiarities and some features of cones and seeds (Tereshchenko, 2006).

Stationary investigations provide methodical approaches of two types. The first one is „true" monitoring that is regularly measurement and assessment of certain parameters of forest ecosystems. The second one is an active experiment, where some changes are provoked in forest environment, and then the investigations does not differ from monitoring approach.

In the plots of „true" monitoring of the Ist Level (extensive monitoring) small number of parameters is assessed in the dense network of plots. In rather small amount of the IInd Level monitoring plots (intensive monitoring) about 300 parameters are assessed. Monitoring data are used for research of spatial & temporal dynamics of forest condition, for analysis of causes and consequences of different disturbances on forest condition, for biodiversity, phytomass and carbon cycle evaluation (Manual ..., 2010; Buksha et al., 2014).

Research on monitoring plots gives the possibility to improve the analysis methods. So T. S. Pyvovar revealed species specific peculiarities and ranges of variability of crown condition parameters (relative crown length, crown density, dieback and foliage transparency) for five tree species (Pyvovar, 2008). She estimated diagnostic signs, which give the possibility to predict the mortality of European oak by parameters of crown condition. Method of complex evaluation of tree layer condition is suggested by the II level monitoring data which consider crown condition, tree damage and mortality (Pyvovar, 2010).

The example of the active experiment are abovementioned experiments of B. I. Gavrilov, research on introduction of alien plants or animals, sands afforestation, mines recultivation etc.

Except „true" monitoring in the regular network, another type of monitoring (so called local monitoring) is carried out in the stands, which grow in the localities with different level of recreation, fire, technogenic pollution (Voron et al., 2008, 2012), clear-cuts, burnt area, forest damage by insects and at some distance from them (Meshkova, 2009, 2011, 2013). The aim of such studies is revealing the peculiarities of change the forest ecosystem parameters in the different distance or in some time after local disturbance.

Another couple of researches is connected with study the consequences of forest damage by foliage browsing insects. Because of felling of weakened stands according to „Sanitary rules in the forests of Ukraine", duration of research in particular foci of foliage browsing insects is rather short. Permanent plots with the largest period of such research are located in the oak stands of Kharkov Forest Research Station of URIFFM. These permanent plots were grounded in the 70th of the last century by M. A. Lokhnatov and M. I. Prokopenko. In the 80th they were monitored by V. L. Meshkova and S. V. Vlashchenko, at the beginning of the XXI century by I. S. Neyko and researchers of Laboratory of Forest Protection. In 2011 radial increment was studied for several trees with well-known defoliation history.

In Luhansk region in 2007—2013 the investigations were carried out in the permanent plots in the foci of pine sawflies (Diprionidae). It gave the possibility to reveal the peculiarities of pine sawflies population dynamics, crown damage, radial increment and tree mortality depending on forest site conditions, forest age and density. Dependence of tree sanitary condition on its initially condition before foliage damage and from defoliation level was evaluated (Meshkova, Kolenkina, 2014, 2016). Similar investigations were carried out in the foci of foliage browsing insects, root rot and in the burnt area in Kharkov region (Zinchenko, 2014). Algorhythms were suggested to predict the threat of tree colonization by stem pests and mortality in the stands, damaged by fire, root rot and foliage browsing insects.

Dynamics of sanitary condition of oak (Meshkova, 2011) and pine (Sokolova, 2016) near the clear-cuts was studied in the case of felling in different seasons and their colonization by stem pests. The measures have been developed to decrease the wood damage by stem pests.

In the pine stands of Low Dnieper population dynamics of the main insect pests was analyzed by frequency, severity and duration of outbreaks. On the base of ranking the stand attractiveness for foliage browsing insects' foci and considering the change the age structure of the stands, the prediction of the threat of foci of these insects up to 2045 was carried out (Meshkova, Nazarenko, 2011).

Data on the dates of swarming and tree colonization by the most common stem pests of Scots pine (*Pinus sylvestris* L.) in the stands of Forest zone, Left-bank Forest Steppe and Steppe of the Left-bank Ukraine in the period of 2005—2014 have been analyzed. Proximity of the date of the beginning of swarming in Tomicus piniperda to the date of stable transition of air temperature over 5 °C, and in Tomicus minor, Acanthocinus aedilis, and the first generation of Ips sexdentatus and Ips acuminatus to the date of stable transition of air temperature over 10 °C was statistically proved. The latest dates of timber removal after winter felling were determined as March 12 for Steppe zone, March 15 for Left-bank Forest Steppe and March 22 for Forest zone. The earliest dates of felling in autumn without risk of colonization by stem pests were determined as September 29 for Steppe zone, September 26 for Left-bank Forest Steppe and September 16 for Forest zone (Meshkova et al., 2015).

Duration of long-term investigations is often discussed (Bakker et al., 1996). As usual the consequences of forest management or natural disturbances must be monitored up to the main felling. At the same time, at any stage of forest development it is possible to make some conclusions.

For example each insect species damage the trees only in the certain age. Particularly unclosed pine plantations are damaged by specific pest complex, among which large pine weevil (*Hylobius abietis*) and bark beetles (Hylastes ater, Hylastes opacus, Hylastes angustatus and Hylurgus ligniperda) take the main part. During 18 years several series of permanent plots were laid in pine stands from their creation up to crown closure. Spread and injuriousness of mentioned stem pests were studied there. It gave the possibility to develop the range assessment of spread and injuriousness of stem pests in unclosed

pine plantations, to estimate the threat for the stands of forest enterprises, to develop the methods and dates of protection of unclosed plantations from stem pests (Meshkova et al., 2015; Sokolova, 2016).

For investigation of spread and injuriousness of pine bark bug in the stands of Novgorod-Siverske Polissya, permanent sample plots were grounded in the different forest site conditions (from very dry poor to fresh relatively rich site conditions) in pure and mixed pine & birch plantations, created from 1972 to 2007. The assessment of pine bark bug population was carried out in plantations of each age range for four years. Thus monitoring covered plantations from 4 to 44 years old. Peculiarities of pine bark bug seasonal development was determined, parameters of its spread in pure and mixed stands. Range assessment of pine bark bug spread was developed considering forest site conditions and stand age and used for prediction of potential foci area on the base of forest inventory data. Optimal years and dates of early thinning are suggested taking into account pine bark bug seasonal development (Bobrov, 2016).

Discussion. The scientific value of permanent sample plots increases over time, and new generations of scientists would make their researches there. Network of permanent sample plots gives the possibility to obtain reliable data, which would be the base of recommendations for forest management.

Conclusion. Long-term researches in the permanent sample plots are the base of field investigations in forest science, forestry, forest protection, forest breeding and forest monitoring and obtained results are the base for recommendations for forest management. The sense of long-term stationary researches is in the regularly repeated assessment of the same parameters by the same methods in the network of permanent sample plots. Stationary investigations provide methodical approaches of two types. The first one is „true" monitoring that is regularly measurement and assessment of certain parameters of forest ecosystems. The second one is an active experiment, where some changes are provoked in forest environment, and then the investigations do not differ from monitoring approach. The succession of generations of scientists is characteristics for long-term researches. However the main disadvantages of organization of stationary researches are connected with lack of funds for regular site visits and inability to equip the permanent plots with modern instrumentation. It prevents or inhibits the complex researches in forest ecosystems.

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SUMMARY

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ДЕЯКІ ОСТАННІ РЕЗУЛЬТАТИ ДОВГОСТРОКОВИХ ДОСЛІДЖЕНЬ УКРНДІЛГА НА ПОСТІЙНИХ ПРОБНИХ ПЛОЩАХ

Мета досліджень — характеристика багаторічних досліджень учених УкрНДІЛГА на постійних пробних площах і шляхи використання нових результатів. Використано дані з архівів УкрНДІЛГА і наукові публікації останніх років. Висвітлено стислу історію стаціонарних досліджень УкрНДІЛГА, дослідна мережа якого нині охоплює два філіяли, шість дослідних станцій і одне відділення.

Приділено увагу змісту та недавнім результатам багаторічних досліджень на постійних пробних площах Інституту та дослідної мережі з питань лісівництва, селекції, моніторингу та захисту лісу. Вказано, що сенс багаторічних стаціонарних досліджень полягає у регулярно повторюваних обліках тих самих параметрів однаковими методами на мережі постійних пробних площ. Одночасно реєструють параметри екосистем, які характеризують ґрунтові умови, поширеність та стан рослин і тварин (комах), а також частоту та інтенсивність чинників зовнішньої дії. Зазначено, що для тривалих досліджень на постійних пробних площах є характерною спадкоємність поколінь учених.

Висвітлено останні результати дослідів щодо рубок догляду, закладених Б. Гавриловим у 1932 році, вивчення географічних культур, закладених з ініціятиви В. Огієвського на початку XX століття та І. Патлаєм у 70-ті роки XX століття. Наведено перелік інших типів селекційних об'єктів, зокрема генетичних резерватів, плюсових насаджень і дерев, випробних культур, клонових і архівно-маточних плантацій. Висвітлено особливості досліджень з моніторингу І і ІІ рівнів, а також локального моніторингу стану насаджень, які перебувають під впливом рекреації, пожеж, пошкоджені комахами тощо. Наведено недоліки організації стаціонарних досліджень, пов'язані з браком коштів на регулярне відвідування об'єктів витрати, неможливість оснастити об'єкти сучасною вимірювальною апаратурою тощо.

Ключові слова: лісознавство, довгострокові дослідження, постійні пробні площі, лісівництво; захист лісу, лісова селекція, лісовий моніторинг.