THE DEVELOPMENT OF FOREST SCIENCE IN LITHUANIA

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1. INTRODUCTION

The onset of forest science development in Lithuania dates from the second half of the 18th century. However, for the last two centuries progress was slow. Forest science took tremendous strides only in the second half of this century, and became a steering force of advances in forestry and a useful partner of other natural sciences. Currently the level of development, the maturity of scientific potential and results rank the forest science in Lithuania as significant part of other sciences and some of its achievements are well known abroad.

In the past Lithuania was famous for its large forests. There was no shortage of wood, and few scientists cared for studying forests. Essentially forest science started developing only after World War I. The foundation for forest science in Lithuania was laid out by Prof. P. Matulionis (1860-1932), the first Rector of the Lithuanian Academy of Agriculture. He was a distinguished forester, scientist and teacher who paved the way for others. At that time the first classification of forest sites appeared (1919), the principles of stand improving were formulated (1920), attempts were made to provide scientific foundation for regulating forest use and taking inventory (1924), and local tables of the growth and volume were set up. Forest science was supplemented by dendrology studies (Rauktys, 1938), florial research (Brunza, 1934, Minkevicius, 1933, Ivanauskas, 1938). B.Baginskas (1940), S. Kripas (1933) started the investigation of forest soils, P.Jusaitis and A. Rubikas (1939) studied cutting methods. While conducting forest inventory, valuable data were received on the growth rates of different stands (Vilcinskas, 1931). Silvicultural literature was supplemented by typological descriptions of forests (Jankauskas, 1935).

In summary, at this time a foundation was laid out for studies of forest inventory and for typological and dendrological investigations of Lithuanian forests. However, in 1938 the Department of Forestry at the Lithuanian Academy of Agriculture and the Experimental Forestry Enterprise in Dotnuva were abolished. Thus, there was no centre stimulating scientific studies of forests. Eventually, Lithuania lost its independence (1940). Many foresters fled the country or were deported to Siberia. At this point forest research completely stopped. In 1944 the Faculty of Forestry was restored at the Vilnius University, and a pool of highly qualified forest scientists were part of it (V. Vaitkus, M. Jankauskas, L. Sernas, A. Koncius, A. Minkevicius et al.). They provided a force of comprehensive research and training for foresters. The investigations were carried out on reforestation and on the species of larch (*Larix*) able to grow in Lithuania (Jankauskas, 1954), on the yield of pine stands, and on the phenology of major tree species. The first state expedition was organized for studying the reinforcement of sand and afforestation of sand dunes in Kursiu Neringa. This was the prototype of organizing a new state forest research organization by transferring the major research from an educational institution - the Faculty of Forestry - to an institution devoted to scientific research.

While reconstructing forestry ravaged by the war the Lithuanian Forest Research Institute was founded on August 7, 1950, in the system of the Lithuanian Academy of Science. Thus, a special forestry research organization initiated its activity by far later as compared to the neighbouring countries (in 1939 in Belarus, in 1945 in Latvia).

The activities of the Institute included the four major programs: (1) forest biology and forestry, (2) reforestation and species selection, (3) forest economics and forest management regulation and (4) forest use. These trends have intangibly changed, but can be identified till the present days.

At the beginning the total research personnel and scientific technical workers numbered only 30. Later, especially in 1970-1980 the number of workers totalled over 200. The Forest Research Institute of the former Soviet Academy of Sciences, the Institute of Forestry and Forest Mechanization, the Forest Technical Institute in Moscow, Vilnius University and other institutions considerably contributed to the improvement of scientific qualification.

To strengthen the experimental basis, in 1957 the Institute established three forest experimental posts (in Birzai, Varena and Kursiu Neringa) and the Dubrava Forest Experimental Station, which covered an area of 15,000 hectares of forest. In 1960 at the Institute the Department of Forest Protection started its activity and in 1961 the Department of Forest Soils and Forest Typology was established. Also, Vilnius Economic Investigation Post was established in 1965, and the Department of Forest Management Regulation and Forest Inventory was founded five years later. In 1974 the Laboratory of Mathematical Models and an Investigation Post of the Plateliai Forest were founded. The Department of Electronic Computation Technique started its activity in 1975.

The administrative dependence of the Institute changed several times. From 1956 to 1963 it was under the jurisdiction of the Ministry of Forestry and Timber Industry, while from 1963 it was under the Central Forest Department of the former Soviet Union. At the same year (1963) the Institute

and the Dubrava Forest Experimental Station were transferred to Girionys (in the Kaunas District) where a laboratory building was constructed. Also an arboretum and Seed Breeding Centre were established. A new residential district for foresters and the Kaunas Forest College were built.

With increase in the number of forest researchers, particularly at the Forest Research Institute, the number of problems under study rose too. The main trends of investigations were as follows.

2. STUDIES OF DENDROFLORA

The investigations of woody plants were stimulated by the fact that in post war years in the republic there were many neglected parks which included rare introduced plants. They needed care and it was imperative that these parks be preserved as a seed basis for arboreta established in forest enterprises. The experience was gained on the introduction of exotic trees. The major species of stands were thoroughly investigated: oak (*Quercus robur*) (Lukinas, 1967; Labanauskas, 1962) spruce (*Picea abies*) (Kairiukstis, 1962) black alder (*Alnus glutinosa*) (Kapustinskaite, 1983), ash (*Fraxinus excelsior*) (Narbutas, 1962). Data on larches growing in Lithuania were summarized (Jankauskas, 1954). A great deal of data were collected on cones and seeds of conifers. The experiences of introducing conifers in Lithuania (Cibiras, 1957) were generalized. At the Institute the forms of *Juglans* species and the perspective of growing them in forests were studied (Ramanauskas, 1967; Dziaukstas, 1958). Inventory of all sites on which exotic trees grow was carried out. The trees found there were registered in a card file. Based on this work, a "Dendrology" book (a monograph) about trees and bushes that grow as well in Lithuania was published (editor V. Ramanauskas, 1963). The second edition was issued in 1973.

Progress was made on collection of woody plants at the Dubrava Forest Experimental Station. In 1961 an arboretum was established. A catalogue of seeds collected was published and exchange of the available seeds with botanical gardens and arboreta in foreign countries intensified. In the 70s the collection in the arboretum included nearly 1,200 species and forms of woody plants. Along with the collections by the Botanical Garden of the Academy of Science, near Kaunas, this was the largest assortment of trees and bushes able to grow in our zone. The objective was to maintain the collection of common dendroflora of the Botanical Garden of Lithuania in Freda, which included decorative trees and bushes and floriculture, to establish in Girionys (the Lithuanian Forest Research Institute) a collection of forest vegetation, in Vytenai (the Institute of Horticulture and Vegetable Breeding) - fruit trees and berry shrubs. In accordance with this system of dendroflora collection, investigations in the above institutions became more specialized.

3. FOREST ECOLOGY AND SILVICULTURE

This scientific trend at the Institute is of crucial importance. We have conducted typological, phenological, hydrological, phytoclimatic and physiological studies on tree species and stand forming. Also, most appropriate ways of tending cuttings and harvesting have been studied, which may help us to increase the productivity of stands and improve their quality.

3.1. FOREST TYPOLOGY

Among significant studies is the biogeocoenotic structure of Lithuanian forests and their classification. The studies were stimulated by the original typological fundamentals, formed by Prof. P. Matulionis for the forests of Lithuania at the beginning of this century. Typological investigations were conducted in the most complex and least studied at that time oak stands (Lukinas, 1956, 1957; Labanauskas, 1960; Narbutas, 1959). Classification of the types of oak stands was prepared on a biogeocoenotic basis (Lukinas, 1956). It provided the foundation for allocating the areas for oak growth and for preparing recommendations to establish oak stands. Also, as a result of studies on black alder stands and on the effect of their site drainage, typological classification of black alder stands was established and forest types were determined (Kapustinskaite, 1962) .

The investigations were carried out on the structure of spruce and establishing mixed spruce-deciduous stands. This led to learning the characteristics of forest types of spruce stands (Kairiukstis, 1962). Also the structure of birch (*Betula* sp.) stands was investigated and their typological classification established (Karazija, 1962). Studies of the productivity of ash stands revealed their phytocoenotic composition, helping to work out the typological classification (Narbutas, 1962).

Typological and inventory studies of forests enabled the scientists of the Institute to learn an overall view of forests of the republic. A book "The Forests of the Lithuanian SSR" appeared in 1962 (Ed. L. Kairiukstis). However, it was already clear then that, despite abundant available material about the structure of Lithuanian forests, yet there was no uniform system of typological classification. Therefore, difficulties arose in applying the typology data to forestry practice. An attempt was made to apply an edaphic screen by P. Pogrebniak to the conditions of Lithuania (Labanauskas, 1958). A system of soil-typological groups was prepared (Vaicys, Labanauskas, 1972).

Over the last two decades the fundamentals of typology created by Sukatchiov, P. Pogrebniak, E. Aleksejev and B. Kolesnikov received considerable attention. It resulted in generalization of abundant material of previous studies and in conducting extensive investigations on biogeocoenoses of all forest species (S. Karazija, J. Jurelionis, V. Vaiciunas, R. Murkaite et al.). Applying a new methodology and mathematical models, allowing to indentify forest types more confidently, the typological classification of forests of Lithuania and the Kaliningrad region was accomplished. The classification possesses the ranks of a system of taxonomic units. Taxons (forest and site types), being the most important in terms of forestry practice, parallel ecologically equivalent site areas. Also presented were biogeocoenotic and forestry characteristics of the series (site types) of all forest types and their potential productivity levels.

3.2. STUDIES OF DIGRESSIVE AND RESTORING SUCCESSION IN STANDS

Studies have been conducted on the regularities of species successions, on the species composition in stands, on the forming of stands and on variation in their structure. For this purpose the method of permanent experimental plots and stationaries has been applied. Over several decades a theory of the formation of mixed stands was developed. It favoured the solution of the problem of regeneration of productive spruce stands and spruce-deciduous forests. The interrelationship between the growth of trees and development as well as the reasons which predetermine the interaction between the trees in mixed stands have been ascertained. The analysis was conducted on the peculiarities of structure in spruce-deciduous stands. Comparative productivity of species comprising these stands and that of individual trees within a species have been determined. It allowed a demutation succession of species to be expressed digitally (Kairiukstis, 1959, 1969). Thus, the theory of changes in species succession, which was created by G.Morozov, extended and provided scientific foundation for improving restoration of spruce stands. The revelation of the limits of homeostasis activity in biogeocenoses and its dependence upon thinning are of extraordinary importance.

3.3. FOREST SOILS AND THEIR FERTILIZATION

Studies of the soils, which are associated with tackling of biological problems, were started in 1950. Later specialized investigations were carried out on the soils. The effect of larch and spruce stands on the soils has been studied. It has been found that in larch stands brown soils may be formed (Vaicys, 1958). Methods of mapping forest soils have been developed. Due to mapping a broader knowledge of the soils is feasible. Studies have been conducted on the exchange of biological nutrients in diverse biogeocoenoses. The dynamics of nutrients, a hydrothermal regime of the soils, the effect of fellings and drainage on the soil forming process, and the impact of soil factors on stand productivity have been determined (Vaicys, Oniunas, Raguotis, Butrimaite, 1966). Moreover, soil quality, economic appraisal of forest soils and the productivity of coniferous stands growing on different soils have been studied.

On the basis of these investigations classification of soil-typological groups of the growth conditions has been prepared. All forest soils of Lithuania have been mapped in detail and in a simplified way. A scale of assessment of forest lands has been constructed (Vaicys, 1965). As a result of the investigations conducted on the genesis of the main forest soils, their classification has been corrected and new soil types singled out (Vaicys, 1975). It appears that, beside other soils, in Lithuanian forests prevail brown soils, as well as pseudopodzolization and loessivation processes. The influence of phytocoenoses on the humus fractional content has been determined, rhizospheric microflora of spruce and birch as well as soil microflora of spruce, birch and pine stands investigated. The biological activity of the soils in these stands and the effect of forest fellings and fertilization on the microbiological activity of the soils have been ascertained (Raguotis, 1968).

Rapid development of chemical industry and abundant mapping data on forest soils already in 1968 enabled us to start specialized investigations for determining the effect of fertilizers and liming on the fertility and biological activity of the soils, on the development of assimilation apparatus of stands and on the volume increment. It has been found that nitric fertilizers essentially enhance the growth of pine stands while potassium and phosphoric fertilizers are several times less effective. They are applicable only to degraded soils. On the basis of the experimental data and on the diagnostic indexes of mineral nutrition of pines the recommendations for soil fertilization for the main forest types of pine stand zones have been prepared (Sleinys, Raguotis, 1976).

Currently, the effect of atmospheric pollution on forest soils is investigated. Regional forest soil monitoring in the network of 8x8 and 16x16 km is conducted according to the International Programme ICP-Forest (Vaicys, Armolaitis, Kubertaviciene, Oniunas, Raguotis, 1994).

3.4. STAND TENDING TECHNIQUES

The peculiarities of forest bioclimate in natural and artificial biogeocoenoses have been investigated. The results have demonstrated that the growth and development of trees largely depend upon environmental conditions. Ways have been found effectively to regulate forest bioclimate and optimize individual tree growth conditions by thinning. Endogeneous factors predetermining different growth and development of trees of various classes have been ascertained. It appears that indole acetic acid as well as gibberellic acid directly influence the increment and crucially affect the rhythm of tree growth (Juodvalkis, 1965, Skuodiene, 1978) . The correlation has been found between the uneven surface of forest cover and albedo. Producing a similar quantity of wood, a non-uniform consumption of the solar energy by trees of different classes within a species has been observed. The coefficient of energy consumption performance has been established, and a method of forming layers in stands worked out. Due to application of this method, increase in the total solar energy capacity in the forest rises to 8% and that in the efficiency of solar energy utilization for wood productivity of stems to 6-7%. It is found to be a theoretical basis of tending cuttings (Kairiukstis, 1966, 1967, 1968, 1972).

The effect of different tending and unclear cuttings on the increment of stands has been studied. In case the intensity of thinning is uniform, augmentation of stand increment by about 10-12% is feasible through changing the relative distribution of trees in classes. Also extreme limits of fluctuation of the increment have been determined. Thinning permits us to enlarge or reduce stand increment after cuttings if the stocking of the remaining stands is identical and if they grow in the same soil-ecological conditions.

These investigations enabled systems and ways of tending fellings and harvesting to be prepared. An original bioecologically-economic classification of trees growing in mixed stands has been presented, objective criteria for selecting trees adopted, and uniform systems of stand forming from productive tree species created (Kairiukstis, Juodvalkis, Karazija, 1968). In two-layer stands the way of harvesting by

two cycles of fellings consisting of six shelterwood cuttings has been prepared (Kairiukstis, Sakunas, 1965). Shelterwood cuttings have been modified in spruce and pine stands.

For the investigation of stand density a number of new regularities has been revealed and experimental stationaries established. Therefore, optimization of stand density became feasible in the whole process of forest growth. The classical theory by Asmann, dominating in the world forestry as an optimizing criterion of stand density, is hardly applicable to the optimizing of the increment over the period of coenosis forming and to stands where tending cuttings have been carried out. A total of 500 experimental plots with multiple investigations has been set up. Over two decades the studies conducted on the intraspecific interrelations enabled a new common biological law to be revealed. It is noted that the interaction between the trees within species varies in ontogenesis. The approach of roots and crowns of trees causes a stress. However, over the period of coenosis forming, a certain phase of tolerance is observed. Because of early approach of crowns and roots in dense plantations, the increment of trees considerably falls. In plantations where trees sparsely grow the approach occurs later, i.e. during generative maturity of trees. Therefore, they easier overcome the stress and their growth rapidly improves as soon as anticoenotic relations appear. On the basis of these studies a method has been developed for optimizing density of trees which grow in plantations and stands (Kairiukstis, Juodvalkis, 1976). Also it has been proved that the optimizing of tree growth beginning with seedlings until trees become mature, can not be based on the optimum parameters of the same factors (density, sum of basal area, etc.).

The entity of the dependence found and newly formulated laws permitted us to develop an original theory of forming maximally productive standard stands. The models of standard spruce, birch, aspen (*Populus tremula*) and mixed spruce-deciduous stands have been constructed. Testing has been done to determine the ways of forming such stands in forests. For calculation of the optimum intermediate fellings a method has been worked out (Kairiukstis, Juodvalkis, 1985; Kairiukstis, Juodvalkis, Jonika, Barkauskas, 1980). The experience shows that natural stands which are grown according to the created standards enable the solar energy maximally to be utilized, the productive potential of the soil used and the possibilities of maximum productivity of stand exploited. The quantity of their production is the most considerable.

Studies of this trend are continued. The fundamentals of ecological sustainability of very productive stands are being prepared (Miksys, 1990).

3.5. FORESTRY ON SWAMPY AREAS

A significant achievement is noted in the field of managing forests on swampy lands. In Lithuania the research was initiated by L.Sernas. A great deal of the problems associated with rational use of swampy soils for growing productive stands have been solved. A study has been conducted on a response elicited by stands to drainage. Besides, the ways of selective drainage of black alder stands, the rate of drainage and the principles of establishing productive stands on drained soils, which are resistant against wind, have been prepared (Kapustinskaite, 1970, 1983).

Further investigations of forestry on swampy lands have revealed a new interrelationship between the biometric indexes of forest transpiration and soil-hydrological and meteorological conditions. Consequently, in the theory of forest drainage hydrological parameters of drainage systems have been calculated. More precise formulae have been derived for ascertaining vertical-horizontal exchange of ground water and the water in swamps, as well as for estimating the optimum parameters of drainage systems (Ruseckas, 1991).

Along with these studies, a number of more precise biometric ways and more perfect hydrological devices have been invented. All of them are patented. Original methods for the evaluation of hydrological efficiency of active drainage systems and for optimizing spatial parameters of felled areas have been presented. These investigations, including the drainage of wet soils by redistributing moisture excess in water basins, by far enrich and broaden the theoretical fundamentals of forest hydrology (Ruseckas, 1994).

3.6. DENDROCHRONOLOGY AND ENVIRONMENTAL STUDIES

Comprehensive dendrochronological and dendroclimatic investigations have been carried out at the Forest Research Institute and later at the Botanical Institute and Vytautas Magnus University (Bitvinskas, 1994). A number of original dendroscales have been constructed (Bitvinskas, Kairaitis, 1979; Stravinskiene, 1979, 1981), and the laws of forming the rings in moist forests analysed (Stravinskiene, 1981). Long-term cyclic fluctuations of the increment of trees, which are typical of the whole northern hemisphere, have been determined (Kairiukstis, Dubinskaite, 1990). Recently, dendrochronological methods were successfully applied to environmental studies, forest monitoring and to the explanation of ecological sustainability of region and species (Ecological sustainability of Lithuania, 1995, ed. by Kairiukstis et al.). The devising of methods for indicating a stress situation in trees and the perfection of regional forest monitoring methodology result from diverse investigations conducted on a response of trees to the effect of environmental changes. Morphological variation in the crowns of trees has been studied in the process of crown closure and matting of roots and in that of coenosis forming. It has been determined that changes in the mass of needles and shoots, as a response of trees to new conditions of the growth, are most informative (Ozolincius, 1985). The impact of light on trees affected by stress (Stakenas, 1992), K^+ion transport via cellular membranes as an expression of a stress situation have been studied (Skuodiene, 1987). It is concomitant of a decrease in the biopotential of trees and increase in the electrostatic resistability of living tissues (Petniunas, 1992). Due to constant impact of artificial "acid rain", proline amino acid accumulates in the needles of trees. This process is described by a typical curve of the reaction of stress-adaptation (Skuodiene, 1995).

Physiological, micromorphological, dendrochronological investigations and studies on the response of trees to environmental changes along with yearly visual characteristics of the crowns of trees in the monitoring network allowed the methods of regional monitoring to be corrected (Kairiukstis, Skuodiene, Vaicys, Ozolincius, Armolaitis et al., 1992). It was feasible to ascertain ecological sustainability of different regions according to the response elicited by trees to environmental changes. These studies are included in the ECOSLIT and International ECE programmes ICP-Forest.

4. AFFORESTATION AND REFORESTATION

In post war years the investigations were carried out on reforestation. It is quite understandable, since during the war forestry was devastated, vast burnt forest areas and cutovers needed to be reforested. Foresters lacked original literature how to reforest and reconstruct the ravaged stands. Over the post war period the scientists of the Lithuanian Forest Research Institute significantly contributed to the science and practice of reforestation. Theoretical fundamentals of forest reconstruction were also developed and effective measures for improving species composition implemented. The experience gained in reforestation accumulated over two centuries was applied. Reforestation types and the choosing of tree species for plantations were based on typological studies of forests, on edaphic conditions and on the laws of stand forming in the future. The aim was to establish valuable, resistant and productive stands. A great deal of investigations were dedicated for reconstructing oak and ash stands and for preventing undesirable conversion of spruce stands to deciduous trees.

The conditions of growing of forests have been investigated in west and south-east Lithuania. The ways of raising pure and mixed plantations have been suggested, the tables of site quality for growing plantations prepared, their density depending upon sites optimized (Daujotas, Kirklys, 1960), and an original technology of dwarfed pine stand reconstruction created (Milaknis, Juska, 1961) .

As a result of comprehensive investigations conducted on Lithuanian oak stands and scientific fundamentals of determining the principles for allocation of the area of oak stands, rational ways of raising oak stands have been suggested and a theory of shelterwood reforestation developed. The effect of seed geographical provenance on plantation growth has been experimentally determined. Classification of the development of oak plantings has been created for assessing plantations (Lukinas, 1967). Studies of the peculiarities of the physiological state of young oaks in different phases of their observation enabled us to prepare the ways of growing oak stands in reconstructed poor juvenile stands (Labanauskas, 1957).

Long-term investigations conducted on swamps provided scientific foundation for the ways of their afforestation. The ways of reforestation and natural regeneration of black alder stands as well as agrotechnique and the rate of fertilization in raising coniferous stands on drained soils have been prepared (Kapustinskaite, 1983).

A technology of establishing seed-plots in greenhouses has been created. The most optimum bioclimatic regime, the rate of seed sowing and the density of seedlings growing under polyethylene shelters have been determined (Juska et al, 1982). A new technology created for establishing a spruce storey in pine stands in a mechanized way is of importance. The questions of preparing plantings and planting seedlings under the crowns have been tackled (Daujotas et al., 1957). As a result of biogeocoenotic investigations, the interaction between birches and pines (*Pinus sylvestris*) in mixed plantations, the optimum admixture of birch in pine stands (Danusevicius, 1973), the types of mixed pine (Daujotas et al., 1971) and spruce plantations (Gradeckas, Malinauskas, 1974), and their optimum density have been determined.

A rather significant work has been done in the field of investigating agroamelioration. Studies have been conducted on the optimum use of lands inappropriate to agriculture and on the reinforcement and afforestation of sands at the seaside. For reforestation of lands affected by water erosion three categories of plantations have been suggested: aesthetic, protective forests and these growing between fields on lands inappropriate to agriculture. Ways have been found to reinforce a protective dune and the sliding ones at the seaside and to reforest burned areas (Daujotas, 1958). A total of 18 willow (*Salix*) species introduced in the forests of Lithuania have been tested. Their technical properties have been investigated and technologies prepared for raising willow plantations (Daujotas, 1959) for industrial purposes. Recently, theoretical and practical search of establishing mixed plantations has been generalized (Gradeckas, 1988). Technologies are being completed for growing willow plantations for energetic purposes by applying wastewater silt of towns.

Abundant data have been accumulated on afforestation, and a large monographic manual "Afforestation" was published (Danusevicius et al., 1991). It is possible to state that the current investigations of afforestation are based on the scientific fundamentals of seed (of plus trees) breeding, forest typology, soil mapping, and the establishing of maximally productive standard stands. It enables the initial density of plantations to be reduced and tending fellings at an early age avoided.

4.1. GENETICS AND SELECTION OF WOODY PLANT SPECIES

Woody plants and their selection are investigated on a rather large scale. The investigation of the forms widespread in the forests of Lithuania and assessment of individual trees and stands according to the external (phenotypical) traits are characteristic of the first stage of studies. By using the criteria of selection and assessment in the forests of the republic 1,351 plus trees have been selected and 216 seed reserves singled out. A total of nearly 100,000 hectares of mature stands was assessed from the point of view of selection. As a generalization of investigations in 1966, references were issued for establishing seed plantations in Lithuanian forests (Ramanauskas, Gradeckas, 1966). Also a material basis for the development of selection and seed breeding has been created.

In 1960 the first seed plantation of pine and in 1963-1965 those of spruce and larch were established.

Over the second period (1966-1975) the investigations on assessment of plus trees, on technologies of managing seed plantations and on growing plantings of the main tree species have been carried out. In this period studies of genetic changeability, inheritance of populations, mutagenesis of trees, early diagnostics and crossing have been initiated and expanded. Changeability of the forms of spruce and aspen has been studied. Intricate heterozygous larch hybrids have been obtained by repeated crossing, the ways were developed for obtaining their seeds in seed plantations (Ramanauskas, Tuminauskas, 1970).

While analysing genetic diversity of spruce forms, caryological investigations (Gabrilavicius, 1970) have been carried out on diferent forms of spruce growing in Lithuania, and mutagenesis of Norway spruce (*Picea excelsa*), Scots pine (*Pinus sylvestris*) and rock pine (*Pinus banksiana*) has been interpreted (Andriuskeviciene, 1972). The peculiarities of the growth of pine and spruce progenies, the inheritance of ramification and the forms of crowns, photo and geotropism of seedlings have been determined. Also an improved technology for raising pine and spruce plantations has been perfected.

Adaptation of the best progenies of pine populations and genotypes, genotypic changeability and the inheritance of traits have been observed while investigating the genofond of pine stands in different regions of Lithuania. Genetic differences exist among the greatest part of populations and provenances. On various sites these differences are expressed differently. The populations, provenances and genotypes differ in ecological adaptation and stability. Reliable differences of stem quality and biomass productivity have been determined between the populations according to the phenotypic stability and adaptation in different ecological conditions. The geographical distance and the influence of different climatic factors on the growth of progenies of the populations transferred from one region to another have been estimated. On the basis of the studies the most perspective populations are selected for investigation and for the establishment of seed plantations of the second generation (Gabrilavicius, 1994; Pliura, Gabrilavicius, 1994).

While carrying out interspecific and geographically distant intraspecific crossing fast growing spruce (*Picea abies x P.morinda* and *Picea abies x Picea alba*) and valuable pine (*P.contorta x P.banksiana* and *P.peuce x P.strobus*) interspecific as well as intraspecific hybrids for the ecotypes from Georgia and the Ukraine (local ecotype) have been obtained. Geographical changeability of pine, spruce and Douglas fir has been elucidated (Danusevicius, Tuminauskas, Cesnavicius, 1987; Danusevicius, 1993), and significant asynchronous flowering of clones, their sexual asymmetry found. Such asymmetry limits cross-pollination and, therefore, genetic quality of seeds and yield diminish. Artificial stimulation of seed plantation flowering has been assessed (Danusevicius, 1987). The above studies of genetics and selection have been highly evaluated at the IUFRO symposium held in Lithuania (Olksyn, 1995).

5. FOREST INVENTORY AND FOREST MANAGEMENT REGULATION

With the aid of investigations of this trend the main inventory indexes of the most widespread stands, their traits and laws have been determined. As a result of the analysis conducted on stem forms of the prevailing tree species, the coefficients of forms and form factors have been established. Tables of the volume of the growing stock have been created for pine, spruce, birch, ash, black and white alder. Also tables of the local site quality and the process of the growth of pine, spruce, black alder, ash, birch, larch and white alder stands have been prepared. Typological tables of the growth as a process have been created for the main forest types of black alder and mixed spruce-deciduous stands, as well as for these of birch and aspen stands with spruce. All the tables are widely applied to forest management regulation and inventory of cutovers (Repsys, Butenas, Jankauskas, Antanaitis, Kenstavicius et al., 1968).

To improve forest inventory practical methods of selective inventory have been devised. Since 1966 such methods have been successfully applied to forest management regulation in carrying out inventory of premature, mature and middle-aged stands. For the perfection of selective inventory methods recommendations for carrying out inventory on large areas have been prepared. The zoning of forests and inventory standards have been analysed. Tables of form factors, and standing timber volume have been created for pine, spruce and birch stands depending upon the height and diameter of trees. In accordance with it site quality and stocking of premature and mature stands has been simplified. Tables of the growth of standard stands have been prepared for the whole Baltic area (Kenstavicius, Kuliesis et al., 1983).

Maturity of forests, the balance of wood accumulation have been studied and the age of stand felling ascertained. Analysis of felling area according to zones has indicated that differentiation based on site quality, forest types and stocking is necessary. Such differentiation is already used in forest management regulation. Owing to the extensive investigations conducted on the soils, forest typology, forest management regulation, inventory and forestry, in the middle of the 60s at the Institute a sufficient number of data were collected to develop a new method of forest management regulation on the basis of soil types (Kenstavicius, Vaicys, Jankauskas, 1966). At the Lithuanian Academy of Agriculture successful studies have been conducted too. Since 1966 in our country forest management has been regulated by means of the new method. As a result of simplified investigation carried out on forest soils, the inventory of stands has been defined more precisely. Permanent experimental plots have been formed by determining perspective purposeful species composition for their stands and a complex of economic measures necessary for the nearest decade. The analysis has been conducted on theoretical and practical questions of inventory of the increment. In Lithuania a significant work has been done in exercising control over forest management regulation and in developing the scientific knowledge of stand increment. Tables of the current increment and marketability of stands have been presented (Antanaitis,

1966, 1981; Tebera, 1980). A broad analysis of inventory data on the forest fund enriched the scientific knowledge of forest productivity and provided experimental foundation for controlling stand productivity (Kuliesis, 1989, 1993). Studies of the increment have demonstrated that long term variation in it is induced by environmental changes. On the basis of inventory and dendrochronology a new method has been devised for the assessment of increment dynamics (Grigaliunas, 1994). This method offers an opportunity to eliminate the impact of climatic factors and to determine the antropogenic effect on increment formation.

Over the last decades the conception of forest use varied in the world forestry. The principles of thorough forest use prevailed. Of concern are functional traits of growing forests, their use for recreation, for protection of the soils and water, and for satisfying socio-hygienic needs of man. Recreational forestry has formed as a new branch of the forest science (Riepsas, 1994). The regulations of managing forests and tending recreation zones in forests have been determined (Kenstavicius, Karazija, 1972).

6. FOREST ECONOMICS

The investigations have been mainly carried out on timber stock. Measures have been adopted for augmenting its productivity and for providing scientific foundation for its use and sustainable development. A project of the development of Lithuanian forestry over 15 years (1951-1965) has been prepared and a general programme of its development in 1957-1970 undertaken. The researchers have presented a prognosis of the development of forestry in Lithuania and in the Kaliningrad region by the year 2000.

Economic aspects of the forest productivity have been investigated and economic stimulation of complex forestry suggested. Also standards have been set for price forming and for determining economic efficiency of different technological processes.

Studies on economic aspects of selective fellings and on the rises of income favoured the development of a method for economic appraisal of a forest enterprise and its lands. Economic models of different selective and clear cuttings have been constructed. Species composition of stands, site conditions and forest operation technology have been taken into consideration. The economic effect of free and group selective fellings has been determined (Ancukevicius, 1970).

After the declaration of the independence centrally planned economy was abandoned. We were given the task of solving problems associated with market economy. Different models of forest ownership forms, which are based on step-by-step privatization, have been constructed. A scheme has been prepared for state and economic forest management. Standards of appraisal of forest lands and forests have been set. They are based on cash income. A method for preparing price-list of the growing stock has been developed allowing for market prices of wood sortments. While solving the tasks of forestry financing, the principles of allocating funds and these of creating the central forest fund have been formulated (Mizaras, 1993).

7. TECHNOLOGY AND MECHANIZATION

These problems are more broadly studied in Latvia and Lithuania. By-production of forest and physical-mechanical properties of wood have been the subject of investigations. The analysis has been conducted on technology of preparation and use of stump wood, on that of wood obtained while carrying out tending fellings, on rational utilization of residues after fellings and on the prospects of obtaining tar from spruce. Physical-mechanical properties of wood of spruce, pine, ash, oak and black alder have been investigated. Technologies and the organizing of harvesting and intermediate cuttings of unclear fellings have been analysed more extensively. Also technologies of shelterwood fellings in spruce-deciduous stands have been prepared (Sakunas, 1966), the principles of technological forest operations (which were the basis of the current logging) formulated. Later by perfecting the organizing of logging the most rational technology for tending and for some shelterwood cuttings of mechanized unclear fellings has been prepared. Besides, the possibilities of trees being left and the preserving of underwood have been determined, as well as the criteria which allow us perfectly to evaluate the quality of wood-cutters work adopted.

Typical technological schemes of mechanized work have been prepared for planting trees under crowns and in pine stands of slight stocking. A hauling equipment for a wheeled tractor, an equipment for loading fire wood and removing it from a cutover, measuring tools for recording the resistance of trees being hauled and for studying the skidding by a tractor have been constructed. Studies have been conducted on the dynamic and static forces affecting a crawler tractor and its hauling equipment in the process of wood hauling. On the basis of investigations a universal hauling equipment tested by a State Commission as well as a hauling equipment without a choker have been invented.

Complex investigations have been conducted on the forces affecting a wheeled tractor in skidding timber. The best ways of removing timber have been ascertained, the specifics of drawing wood and the characteristics of skidways analysed. A new hauling equipment with a telescopic boom has been constructed. For regulation of artificial fog in a greenhouse an electronic apparatus with measuring elements has been designed (Juska, 1972).

Investigations conducted on the effect of logging technique on the soil and forest environment permitted us to determine the indexes of soil compaction, water permeability and decrease in aeration depending upon the site conditions and technique used. On this basis the technologies of unclear and tending felling, which enable us to reduce the damaging effect of machines on the forest environment have been perfected (Kairiukstis, Sakunas, 1993).

8. THE INVESTIGATION OF FOREST PROTECTION

Comprehensive research in this field was initiated in the middle of the 50s. The spreading of elm plague (Zuklys, 1957), hard aspen fungi and the biology of its pathogens (Mikalkevicius, 1959), as well as pests of pine stems have been investigated (Valenta, 1960).

After the establishment of the Department of Forest Protection at the Lithuanian Forest Research Institute constant and purposeful studies of forest protection issues were started. Diseases of the needles of pine (Rimkus, 1960), pests of pine and spruce stems have been investigated (Valenta, 1964, 1969). The spreading, biology and ecology of the main pest species, the reasons for their outbreaks have been determined, the tables of diagnostics created, the measures for combating the diseases and pests adopted, and regional technologies for practice prepared. They are used currently as well.

In post war years due to the establishment of pure pine plantations on vast areas inappropriate for agriculture good conditions were created for pest breeding and root diseases in young stands. In 1957-1967 the outbreak of shoot-beetles, especially summer shoot-beetle (*Evetria duplana* Hb.), infested from 3 to 5 thousand hectares of forest. Rather extensive outbreaks of bark-beetles (*Ips* sp.) and weevils (*Pissodes* sp.) have been observed. The investigations resulted in preparing an integrated way of combating shoot-beetles and the chemical one for combating weevils and bark-beetles (Valenta, Sakuniene, 1969; Ziogas, 1976; Lazdinis, 1986).

In south-east Lithuania young pine stands, particularly one year old plantations, were considerably devastated by *Melolontha melolontha* and *M. hippocastani*, and other root eating pests. The spreading of economically damaging pests and their bioecology have been ascertained, calendars of mass injuries of pests on large forest areas created and an original way of combat prepared (Gavelis, 1970). Studies have been conducted on conifer forest for elucidating the spreading of root fungus *Fomitopsis annosa* and its biological questions as well as for determining the microorganisms-antagonists of the root fungus (Vasiliauskas, 1964). Also technologies have been prepared for rehabilitation of damaged pine stands (Vasiliauskas, Kazemekiene, Pimpe, 1975; Vasiliauskas, 1989). To combat the beating of pine seedlings down caused by infection, original biological preparations have been found (Vitkunas, 1971).

The investigations have been carried out on forest ants, ichneumons, braconids and other useful entomophags, and technologies prepared for breeding them in stands and cutovers (Valenta, Jakaitis, Gavelis, Pusvaskyte, 1972; Jakaitis, 1975).

By expanding applied forest protection in 1969, at the Institute a special group has been established. It was given the task of investigating the newest preparations used to combat pests and diseases. Along with the effectiveness of preparations, their phytotoxic properties, persistence, as well as their fate in the forest environment and impact on the viability of entomophags have been studied (Kilikevicius, 1978). The ways of applying new preparations have been found, which destroy pests and preclude the beating of spruce seedlings down (Valenta, Ziogas, 1976). Studies have been conducted on attracting spruce bark beetles (Gavelis, Jakaitis, Zolubas, 1987, 1993), on application of insecticides for protecting the seeds of spruces from conobionts-phytophags (Dumcius, 1987), on root decay of spruces and on the measures adopted for decreasing the damage (Vasiliauskas R., 1989). Currently, complexes of forest entomophags and their succession are investigated, the losses caused by the main insects-pests evaluated, integrated measures of forest protection adopted. Chemical and biological preparations unharmful for the environment have been applied.

The institute provides methologies for practical forest protection measures and gives consultations for the Station of Combat Against Forest Pests and Diseases.

8.1. GAME AND HUNTING MANAGEMENT

The ecology of roe, deer, elk and boar, their effect on agricultural crops and forests have been investigated. The territorial capacity has been determined and the fundamentals of using these populations and regulating their density prepared (Padaiga, 1965, 1968; Baleisis, Padaiga, 1975; Petruzis, Padaiga, 1979, 1980; Petruzis, 1985).

The ecology and etiology of grey hares have been investigated, the demand for food, the formation of the behaviour ascertained, and relative conservatism of their breeding, the problem of superfat hares, the changeability of sex ratio, the critical periods of their growth determined. The growing of hares in open-air cages and setting them free to the areas of hunting have been investigated. The negative (sterilizing) effect of pesticides on the breeding of hares has been found (Bielova, 1988, 1992). The dependence of infection of roes by parasite diseases on their density and the factors predetermining the deaths of roes in winter have been determined (Padaiga, Marma, 1970). Studies have been conducted on the significance of economic measures for the productivity of winter pastures of deer and on the ways of increasing natural forage resources (Padaiga, 1977). Economic, mechanic and chemical measures for protecting forest plantations from deer have been adopted. A regulating system for large forest fauna populations and their habitats is worth mentioning (Padaiga, 1984). The methods to assess the damage caused by the animals to the forest enterprise has been developed (Padaiga, Mizaras, Vasiliauskas, 1994). The zoning of the area of Lithuania for game has been carried out and the standards to breed them set. The prospects to decoy deers into enclosures for the winter in the forests on the plains has been investigated (Bielova, Padaiga, 1995). Of importance is the program of integration of forest and hunting management. Currently, at the Faculty of Forestry forest engineers - experts of hunting - are trained. They are concerned about wildlife protection and hunting.

9. PUBLICATIONS AND SCIENTIFIC DISCUSSION

Comprehensive research and scientific activity is reflected in the publications of the Forest Research Institute and the Faculty of Forestry at the Lithuanian Agricultural University. Over 45 post war years the Institute issued 34 volumes of proceedings which comprise 573 printer's sheets. A total of 315 monographs, books and booklets have been published. Some books such as "The Forests of the Lithuanian SSR" (1962, 368 p.), "Dendrology" (I and II editions, 1963, 1973, 384 p.), "The Forest Management of the Lithuanian SSR" (1968, 220 p.), "Forest Ecology" (1979, 310 p.), "Silviculture" (1991, 351 p.) are of scientific and educational

significance.

In the cooperation between the three baltic republics and Belarus, the Lithuanian Forest Research Institute was a major coordinating organization at the Agricultural Academy of the former Soviet Union and in 1973-1981 issued a series of publications "Science for practice" (in Russian). A total of 6 books were published in which the results of the research conducted by scientists of the Forestry Institutes of the three baltic republics and Belarus, and by those of higher schools, is reflected. Recommendations were made how scientific achievements should be applied to silviculture. Additionally, in post war years the scientists of the Forest Research Institute alone published 3,890 scientific papers. It comprises 2,700 printer's sheets.

While developing the forest science over 40 International regional and national scientific conferences were held. The reinforcement and reforestation of sands (1955), rational use of wood (1960), mechanized cultivation of the soil for forest plantations (1968), investigation and mapping of forest soils (1961) were discussed. Scientific conferences were held on the problems of increasing forest productivity (1963), shelterwood and selective fellings (1966), and on the forming of highly productive standard stands (1975, 1979). At the international meetings, perfection of the methods of forest management regulation (1965, 1972, 1977), dendrochronology and dendroclimatology (1968, 1978, 1981, 1991), genetics, selection and seed breeding (1976, 1994), and forest protection (1969, 1978) were discussed. The protection of the genofond (1985), tending of recreational forests (1987), ecological sustainability of regional development (1987) and methodical questions of regional forest monitoring were also discussed at the workshops (1991, 1992, 1993, 1994).

10. FINAL REMARKS

The forest science in Lithuania has no hundred-year traditions. The beginning of its development was in the 19th century, and as a science it was formed at the turn of this century. Between the two wars (1926-1930 and 1934-1938) they were developed by enthusiasts encouraged by the former Faculty at the Academy of Agriculture and by the journal "Our Forest" founded by the Society of Foresters.

German and Russian forestry schools positively affected Lithuanian forestry. Precise technical measures of German classical forestry, and Russian natural-historical and geographical aspects of forestry and their biogeocoenotic conception also made a great influence on the development of forestry in Lithuania. The contacts of foresters of the baltic republics as well as the effect of IUFRO enriched the diversity of forestry research and broadened the perception of forests.

In post war years, after the Lithuanian Forest Research Institute was founded, and a number of young scientists finished studies in post-graduate courses at the forest research centres of the former Soviet Union, the experimental forest research was set on a large scale. The scientific centre from the Faculty of Forestry was transferred to the Forest Research Institute. In 1960-1990 the biological trend of silviculture flourished indeed. Over 10 Hab. Doctors of science and 40 Doctors were employed at the Forest Research Institute, at the Dubrava Forest Experimental Station and six research posts. Keen insight and forest policy pursued by A. Matulionis, the Minister of Forestry, enabled us to create a firm experimental basis of the Institute at the Dubrava Forest Enterprise covering over 15 thousand hectares of forest (Arboretum, Seed Breeding Centre, etc.). It stimulated far going forest research and rational use of forest resources. The achievements of forestry in Lithuania were known not only in the former Soviet republics but also in the West. Outstanding foresters were awarded National Prizes (1972, 1985), gold, silver and bronze medals at the then exhibition of Agricultural Achievements. In 1992 the author of this paper was awarded the International Wilhelm Leopold Pfeil Prize for significant contribution to the European forestry.

Currently, the forest science in Lithuania encounters difficulties. Due to economic crisis after the declaration of the independence research is conducted on a smaller scale. Only one half of the scientific technical workers remained at the Forest Research Institute. Because of insufficient financing the possibilities of research expeditions diminished. A decision made by the Ministers of Forestry was detrimental to the forest science. The Institute lost its experimental basis that was created over decades. The process of division continues even now. The relations with research institutions of the CIS countries ceased. The integration of the Forest Research Institute and the Faculty and attempts made to transfer experimental investigations to the high school do not yield quick results. The declared financing of the programmes undertaken by the Forest Research Institute is insignificant. The scientists of the Institute participate in the scientific programme "Ecological Sustainability of Lithuania" (ECOSLIT) and the International Programme ICP-Forest. The contacts with scientific institutions of forestry in the West, particularly with those of Germany and Scandinavian countries, have by far improved. They provide scientific literature and some research equipments and offer the possibilities to perfect the qualification of foresters. It will undoubtedly help to overcome the difficulties of this period. However, it is not sufficient for the normal development of the forest science.

CURRENTLY, THE ATTENTION IS FOCUSED ON THE SOLUTION OF THE THREE PROBLEMS:

1. Studies of the biological diversity and sustainability of forest ecosystems.
2. The productivity, protection and use of forests and solving of economic problems.
3. The analysis of the genofond of forest vegetation, its preservation and use.

It is hoped that the linking of the remaining scientific potential of the Institute and high school, as well as the research conducted by the students of the Forestry Faculty will enable us to solve the above mentioned problems and to accept the challenge of the 21st century to the forest science, which will be formulated at the 20th World IUFRO Congress.

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