SCIENTIFIC AND APPLIED CONTRIBUTIONS

Prof. M. Lyubenova's scientific works are in the field of phytoecology, with an emphasis on the functional features of plant communities. A characteristic feature of the scientific publications related to the ecological thinking of the author is her complex view of the studied objects. She uses various methods and indicators to solve the set tasks, often demonstrating originality in the combination of methods, approaches, and indicators, as well as in the development of models, new methods, and approaches. For this reason, the separation of thematic areas is quite difficult since the publications are directly or indirectly related to each other. However, the scientific production of Dr. M. Lyubenova can be conditionally examined in five thematic directions.

I. CONTRIBUTIONS TO THE FIELD OF FUNCTIONAL BIOCENOLOGY, MODELING AND ASSESSMENT OF TERRESTRIAL ECOSYSTEMS

Hardly anyone needs to be convinced of the importance of functional studies of macrobiological systems (MBS), which provide information on the state and possibilities of ecosystems, their importance for global cycles, the state of the biosphere, the possibilities of MBS to provide ecosystem services to human society, for biomanagement, and for the need to limit safe and sustainable use. Forest ecosystems rank first among other terrestrial ecosystems in terms of their degree and versatility of ecological and economic importance. To a large extent, all other natural resources in a given area depend on them. The species composition, biomass, production, and included chemical elements in forest plant communities determine more than 80% of the features of all other coenoses and, in general, the functioning of the ecosystem. The study of the other components is rather necessary to determine the regulatory mechanisms in the ecosystems, to indicate changes and diagnostics. Based mainly on the data for functional indicators, the following are possible: 1. The development of various types of models for simulating the "behavior" of macrobiological systems for the purposes of assessment and prediction; 2. Modeling of the ecotoxicological effects of pollutants; 3. Assessment of potential and actual ecosystem services; 4. The development of strategies for the sustainability of services related to limiting the use and introducing measures for their protection.

The difficulties in conducting functional studies of ecosystems are undoubtedly enormous due to their complex structural and functional organization, the need for more complex expertise and stationary conditions, high labor intensity, longer duration, significant financial resources, changes in environmental factors, inability to reproduce obtained data, lack of controls for most indicators, and more. These factors

have resulted in a lack of sufficient information about the functional specificity of ecosystems, inadequate functional classification, and the absence of standardized methods and indicators for diagnosing ecosystem health. However, progress has been made in this regard with the development of projects related to monitoring forest ecosystems in Europe and the assessment of ecosystem services. The lack of sufficient knowledge has resulted in an accelerated rate of negative anthropogenic influence on natural systems, which outpaces our knowledge of their functioning.

To compensate for this negative trend, the ecological community is mainly engaged in continuous inventory related to determining the threat category of species and habitats, their mapping, monitoring, and conservation. Inventories are mainly based on structural indicators, which are less reflective of functional interrelationships. However, it's important to assess the potential and real importance of the services provided by the mapped habitats. To do so, it's necessary to consider their characteristics such as the occupied area, species composition and structure of phytocenoses, amount of dead mass, soil characteristics, influencing anthropogenic factors, and others. Characterizing their functional opportunities as a source of biomass, bioproduction and oxygen, as a depot of carbon and chemical elements, and as a local and global participant in biological and biosphere cycles is extremely important. This provides a basis for a real assessment of their potential, the criteria for safe use, the selection of indicators for condition monitoring, and the construction of strategies for effective protection.

The main part of the published works of Dr. M. Lyubenova refers to this thematic direction.

A. GROUP OF CONTRIBUTIONS FROM THE RESEARCH OF STRUCTURAL AND FUNCTIONAL INDICATORS OF PHYTOCOENOSES, MAINLY FOREST AND THEIR CONDITION:A1; B1, B3; C8, C9AB, C10, C13; D16, D18, D20, D33, D34, D35, D37; E1-10, 11, 15, 17-19, 23-28, 30, 33, 34, 37, 39, 43-45, 47, 52, 55, 58, 59, 68, 70, 71; F1, F2-8, F15, F16, F 18-22, F26-28, F30, F32, F38, F41-42, F46-49; G1 – 2, 4, 5, 6, 9-17; G2 – 2-8, 10-12, 16. In the scientific publications, 8 scientific and 7 applied contributions were formed.

This thematic sub-area includes published studies on the functioning of forest ecosystems such as chestnut, beech, oak, white pine, and spruce. It characterizes some functional indicators of a beech ecosystem with co-dominant common yew, of a Greek juniper ecosystem, of grass ecosystems from the Dragoman marsh, and on the grass communities from the "Sinanitsa" pasture in Central Balkan. The main emphasis of these studies is directed to sites that are strongly influenced by anthropogenic activity but are locally widespread or are widely distributed elements of the vegetation that are important for protecting biodiversity, health, life, and culture of the population. Chestnut trees in PP "Belasitsa", oak in the Western Stara Planina and Pre-Balkan National Park, yew in the Central Balkan National Park, and juniper in the Tisata reserve are some of the sites of interest. Some of the published studies are among the

first existing for the country. Attention is also directed to forest ecosystems representative of the country, having a pronounced economic and ecological importance - beech, oak, white pine, and spruce.

The originality of these studies lies in the use of a complex set of indicators and coefficients for characterizing the tree floors, ground biomass, production of plant communities and their structure, annual fall and litter. In many of the publications, the chemical composition of the plant mass was investigated and the coefficients of biological absorption, acropetal coefficient, etc. were determined. A characterization of the biological cycle was made in terms of capacity, intensity, and chemistry, as well as biomass energy reserves. All the studied indicators were evaluated according to the existing scales, and where possible, a general assessment of the condition, prognosis, and recommendation was made. The studies of underground biomass and carbon stocks in forest ecosystems representative of the country are also original. The available information on the amounts of underground biomass and its potential as a carbon sink is scarce in the world literature.

The functional studies were carried out under two international projects, three projects from the National fund of Scientific Research, and four university projects. The results are summarized in a dissertation, two monographs, four books and manuals, seven book chapters and thematic collections, 36 journals with an impact factor, 29 non-indexed journals, and 23 proceedings of scientific forums.

A 1. Scientific contributions

1. A co-authored functional study of the chestnut ecosystems of the Berkovitza Balkans using a set of structural and functional indicators to assess the current state has been published, which is among the first such studies for this vegetation.

Summary results: An assessment of the health status of the common chestnut formation in the area of the town of Berkovitsa was made and some of the ecological factors influencing its decline were discussed. A phytocenotic, taxation analysis and an analysis of the health status of the trees were made; the content of the heavy metals copper, zinc, iron and cadmium in the soil and in separate phytomass fractions of the species was determined, and the biological absorption coefficient and the acropetal coefficients were calculated; the acidity and nitrogen content of the soil were determined; the nematode fauna was studied and its influence on the existing decline was commented.

The research was funded by a university project and was published in a Bulgarian journal.

2. Co-authored complex stationary functional studies of the common chestnut forests in the "Belasitsa" PP using a large set of functional evaluation indicators, which are among the first such studies for this vegetation.

2.1. For the first time, differentiated data on the biomass and production of the individual floors are given.

2.2. For the first time, differentiated data on the biological cycle such as capacity, chemistry and intensity are provided.

2.3. For the first time, data are given on the content of 9 chemical elements in different fractions of phytomass, such as the coefficient of biological absorption and the acropetal coefficient of the elements by fractions.

Summary results: In a series of publications, the stocks of phytomass and the net annual production of the tree floors were determined, which varied greatly in the studied chestnut communities from 73 - 206 t/ha; in the shrub layer - an average of 560 kg.ha^{-1}, distributed between the overgrowth and undergrowth, lower than typical for this type of forest and with 5% participation of the Oriental hornbill; in the grass floor - an average of 29 g.m^{-2}, with the phytomass of mixoherbosa prevailing, the reserves are close to those quoted for the grass floor of this type of forest, they also depend on the age and management; The net annual production of the tree floor has been determined - from 6 to 15 t.ha^{-1} or about 7 to 8% of phytomass stocks; a characterization of the dynamics of stem growth in terms of diameter, height and amount of accumulated wood was made for the period of existence of the community; the production of the shrub floor is on average 303 kg.dka^{-1} with 53% participation of the understory; The content of 6 macro- and 5 micro-elements in different phytomass fractions was investigated, the biological absorption coefficients (BAC) and acropetal coefficients were calculated. The highest is the BAC of Zn, which is the only one of the 4 investigated metals that accumulates in the phytomass. Its maximum value is 34 mg.g^{-1} in 10 and 50-year-old wood. Macroelements participate with 76.65% in the phytomass, with over 99% of the amounts of macro- and microelements accumulating in the stems and old branches. Annually, the stocks of macro- and microelements in the phytomass increase by 27% and 22% through the production. The leading elements in the cycle are N, Ca, Mg and Cu for the 120-year-old forest and Ca, Mg, Mn for the 45-year-old forest. According to its chemistry and capacity, the biological turn over belongs to the group of Na-Ca ones with medium capacity (0.26-0.8 t.ha^{-1}), it belongs to the class of calcium-subboreal turn over, characteristic of deciduous forests. In this case (predominant participation of N), a certain deviation towards the nitrogen-subtropical class is observed. On the basis of the obtained functional indicators that related to the forest health and the authors' own views, general assessments of the ecosystem state were made. The concept of the term "forest health" was developed, in which the character of ecosystem as integral system should be taken into account and functional indicators should be included in the assessments.

A significant part of the researches was funded by an international, national and university projects and was published in a thematic collection, 2 international and 1 Bulgarian scientific journal and in 3 proceedings of scientific forums.

3. A co-authored study of the amount, structure and content of carbon in the underground biomass of representative forest ecosystems in Bulgaria, which has a pioneering character for the country and is among the few existing studies worldwide.

3.1. For the first time in the country, differentiated data on fine and coarse roots are given.

3.2. Original data were obtained and conclusions were drawn about the dynamics of the biomass of fine and coarse roots in different forest communities.

3.3. For the first time in the country, aggregated data on the biomass of yang trees roots, as a separate element of the forest ecosystem, have been collected.

The larger part of developments were financed by NFSR, and the results were summarized in 1 monograph and 3 publications in international journals, two of which have an impact factor.

4. Published (in co-authorship) are original functional data for *Fagus sylvatica* L. communities from Western Stara Planina.

Beech forests have important economic and ecological significance for the country and the establishment of factors that disrupt their functioning is important for the environment and economy.

Summary results: mulch reserves, the amount of annual litter-fall (3.2 to 4.2 $t.ha^{-1}$), its fractional composition and the total intensity of the biological turn over were determined (litter fall-mulch coefficient was 1.3 – 2.1, intensive – inhibited turn over). An intense turn over is obtained for the communities located in the immediate vicinity of a highway - disturbance in intensity due to pollution. The content of N, Ca, K, Pb, Zn, Mn and Fe in the soil, mulch and fractions of the litter-fall was investigated and the elements intensity of turn over were determined. It was established that: the soils are characterized by an acidic reaction, high content of Fe, Mn and N and low content of Ca and K; lead and zinc concentrations are also high; Mn accumulates in leaves and acorns, and Fe in acorns; higher than the typical intensity of Zn and Ca turn over for these type of forests.

The researches was funded by NFSR and was published in international journals.

5. Published (in co-authorship) are original modern functional data for *Quercus cerris* L. and *Q. frainetto* Ten. communities (91M0, Natura-2000) from the "Western Stara Planina and ForBalkan" and an assessment of their condition.

Summary results. The following were studied: biomass, net production, their structure, the dynamics of wood production; the defoliation and discoloration of the crown, the damage coefficient; the chemical composition of the soil, litter-fall and mulch, also the intensity of the biological cycle, etc. According to

the data obtained for the biomass in the above-ground and underground spheres of the communities, the studied xerothermic ecosystems refer to bal 8 (300.1-400 $t.ha^{-1}$), characteristic for the deciduous forest ecosystems. The distribution of plant mass in overground perennial organs and leaves is similar to other published data: 60-81% and 1-3%. The percentage of underground biomass is higher than the quoted data (17-29%), which may be a result of the coppice nature of the forest. Negative trends: low average age of seedlings, in the grass floor; tendency of xerophytization - increase in the number of shrubs, degradation of the tree floor and increase in the number of dry trees; high content of Mn (over 0.05 $g.kg^{-1}$) and Fe (over 0.1 $g.kg^{-1}$), also slightly higher content of Cu (over 0006 $g.kg^{-1}$) in the plant mass, very low intensity of Fe turn over and high intensity of K turn over. Nevertheless, these forests have potential for reproduction. If well managed, they will improve their condition and increase their ecological, social and economic importance.

The researches has been funded by an international and national projects and has been published in journals with an impact factor.

6. Original functional data (in co-authorship) were published regarding the state of the communities of conservation-important trees and their communities - *Juniperus excelsa* M. B. and *Taxus baccata* L.

Summary results: the floristic similarity and species composition of Grecian Juniper communities, also the composition and abundance of the nematode fauna, the content of Cu, Zn, Fe, Cd and Pb in the soil and in different fractions of the juniper phytomass were investigated. The acropetal coefficient and the biological absorbtion coefficient were calculated. No great deviation was found in the research indicators and it was concluded that the decline of the communities is probably related to climatic factors and the particular sensitivity to them, due to the fact that the juniper tree is in the northern parts of its range. An analysis of historical facts of the distribution of the Grecian Juniper in the past and now, of the economic importance in the past and now, and conclusions about the recognition of the species have been made. Similar studies have been conducted on yew. Research has been done on university projects and has been published in international journal and scientific forum proceedings.

7. Original data on functional indicators of grass communities from protected areas were published (in co-authorship) and an assessment of their state was made.

7.1. Comparative data on phytomass and its structure (participation of agrobiological groups) in different ecological types of grass communities (hydromesophytic, mesohygrophytic and mesoxerophytic) from the vegetation in the "Dragomansko Blato" reserve after its partial drainage have been published.

7.2. Comparative data on phytomass, net production, their structure (participation of agrobiological groups) and the content of N, P and K in it have been published for the formations of

***Deschampsia flexuosa* (L.) Trin.**, ***Nardus stricta* L. and *Agrostis capillaris* L., which form the vegetation of the high mountain pasture "Sinanitsa" in the National Park "Central Balkan" have been published and others.**

8. Data on the calorific value of different phytomass fractions have been published and the energy reserves and efficiency of oak ecosystems, etc., have been calculated.

A 2. Applied Contributions

1. A comprehensive ecosystem approach was formed, including a set of functional indicators, to assess the state of forest ecosystem.

2. A revision was made regarding the content of the term "forest health" - it was proposed that the term also include indicators reflecting the integrity of forest ecosystem.

3. A comprehensive methodology for conducting scientific research on the underground biomass of forest ecosystems has been formed.

4. Assessments have been made of forest communities of conservation importance, which can be used in the development of the PU of the protected territories and zones for their sustainable management.

5. The research done on representative forest ecosystems can be used in the management of forest resources and carbon emissions.

6. Methodological approaches and research results can be used for the purposes of forest monitoring.

7. The data from the functional studies served to complete the international on-line database - TRY, also to complete the biomass database and the database on the structural and functional features of forest habitats in the southern part of Europe.

B. GROUP OF CONTRIBUTIONS FROM THE USE OF DENDROCHRONOLOGICAL METHODS FOR FUNCTIONAL ASSESSMENT OF FOREST ECOSYSTEMS (THROUGH THEIR EDIFICATORS) AND MODELING (B2; C7, C14; D17, D19; E12, E16, E20, E22, E35-36, E38, E40, E42, E46, E48, E51; F17, F23-24, F33-34, F44; G1 – 7, 8, G2 – 13, 19, 21) **–** 5 scientific and 6 scientific-applied contributions.

The possibilities of dendrochronological methods for evaluating the influence of the complex of ecological factors on the functioning of forest ecosystems strongly attract the attention of the author in her functional studies for the following reasons:

- deep biological validity of these methods: they are based on the highly expressed sensitivity of the cambial tissue to seasonal changes in the hygro-thermal regime, leading to the formation of early and late wood and the differentiation of annual rings, having corresponding features under the influence of the complex of environmental factors of habitat;
- formation of a pattern characteristic of each habitat and species of the cross-section of the stem ("sequence" of narrow and wide, darker or lighter annual rings), in which ecological information is encoded;

- availability of a developed statistical apparatus, allowing elimination of the influence of age on radial growth, amplification, identification and quantitative assessment of growth-limiting environmental factors;
- a unique method with the ability to track the radial growth and characteristics of the annual rings for a set of years, a necessary condition for the preparation of an assessment and forecast.

In the previous period (in co-authorship) the theory and methodology in the field of dendrochronology were reviewed and summarized and the only book of its kind in Bulgaria - Dendrochronology - was published, in which the biological and ecological foundations, the diversity and peculiarities of the existing trends in dendrochronology are explained, some of which are formed as independent ones. Its publication gave impetus to dendrochronological research in Bulgaria. The author published a number of studies, developing the field of dendroecology, applying original approaches independently or in co-authorship. The emphasis of her research is on tree species of conservation importance and their communities in protected territories and zones - *Juniperus excelsa* M.B. in the Tisata reserve (G5), *Taxus baccata* L. in the Central Balkan National Park (G1), *Pinus peuce* Griseb. and *P. heldreichii* Christ. in NP "Pirin" (F8), *Castanea sativa* Mill. in Belasitsa National Park and in Berkovskiy Balkan, *Picea abies* Karst. and *Fagus sylvatica* L. in Biosphere Reserve "Chuprene", *Quercus frainetto* Ten. in the "Sokolata" reserve and "Western Stara Planina and For-Balkan" protected areas etc., *Pinus nigra* Arn. in the maintained reserve "Gabra"; also on *Pinus sylvestris* L. and *Pinus nigra* Arn., widely distributed in the vegetation of the country in natural and artificial communities; dendrochronological studies of *Quercus rubra* L. and *Q. robur* L. from park areas in the Sofia area - Borisova gradina, Vrana park, Zapaden park, Knyazhevo were carried out, which are important for maintaining a better microclimatic, sanitary and hygienic environment for the capital region. In these initial studies, along with traditional indicators - taxonomy, tree defoliation rate, species composition, storey and dominant structure of forest communities, etc., dendrochronological methods are applied to analyze and model the radial growth of the stems, to establish the growth descriptors regression models and periods of reduced growth (with a growth index below unity); if possible, the sensitivity of the rows, the indicative value of the growth indices for the rows of annual rings, also for the rows of early and late wood, growth-limiting environmental factors were investigated. In some of the studies, the months in which precipitation amounts or temperatures were of primary importance for the formation of stem wood growth were identified. Against the background of the dynamics of the growth index of the obtained model rows, an attempt was made to assess the condition and outline future trends in the development of the stands. Dendrochemical studies have been carried out on the content of chemical elements in the wood and bark of chestnut and Hungarian oak, which are preliminary, but the results are valuable, due to the small number of studies available in this area, the difficulty of conducting them, associated with sampling and

the high cost analyses. The obtained results can be the basis for expanding the research and searching for a statistically reliable relationship between the pollution of the environment, the content in the wood and the bark of the studied elements - pollutants and the established stress periods. In one of the publications, a dendroecological assessment of the degree of adverse influence of *Loranthus europaeus* L. on the radial growth of the stems of slightly and moderately damaged trees in the Natural Park "Belasitsa" was made. The research, with few exceptions, has been carried out mainly on internal university projects, jointly with master's students and doctoral students. They were published mainly in collections of reports, and some in Bulgarian journals. One publication is in the field of dendroclimatology - in co-authorship, a reliable reconstruction of the precipitation in South-Western Bulgaria for 200 years was made based on the obtained trend for the dynamics of the growth index of a Hungarian oak tree stand in the “Sokolata” Reserve.

In her subsequent research, the author focused on the identification and analysis of statistically proven stress periods for the sample and the corresponding stand, called "eustress periods", the introduction and precise definition of the term "eustress", or true stress, where the growth index is below 1 (It<1), but the biological system does not lose its adaptive capabilities and, under favorable conditions, can regain or increase the intensity of radial growth (It≥1), in contrast to the "distress" state, where the outcome is lethal. Statistical limits have been introduced for determining eustress - (It<1)av - □, where □ is the confidence interval of the mean for the range It<1 at a confidence level of 0.05. Due to the presence of differences in the growth potential of the individuals of tree population (differences in the size of the seeds, or in the competitive capabilities of the resulting shoots, also known micro-differences in the environment - composition, density and age of the individuals in the groupings and mosaics; differences in the significance of the influencing environmental factors, etc.) usually there is no complete overlap of the eustress periods for the individual probed trees of the forest community. This necessitated the introduction of a number of statistical indicators, such as cardinality - Card. and covererage - Cov., also the coefficients K and Ct, by which to unify the safe eustress periods for the samples and to be able to make comparisons. Three indicators for the assessment of eustress were also introduced and defined - frequency per 100 years (F), duration (D) and depth (A). 5-level scales have been developed to evaluate these indicators for different types of trees. This approach to stress analysis is inherently holistic, as the ongoing physiological processes (mechanisms) leading to a reduction in radial growth are not considered in detail, but the end result – the formed annual ring – is analyzed.

Due to the presence of differences in the growth potential of the individuals of the population (differences in the size of the seeds of the mother tree of seed origin, or in the competitive capabilities of the resulting shoots, also known micro-differences in the environment - composition, density and age of the individuals in the groupings and mosaics; differences in the significance of the influencing

environmental factors, etc.) usually there is no complete overlap of the eustress periods for the individual probed trees of the forest community. This necessitated the introduction of a number of statistical indicators, such as cardinality - Card. and cover - Cov., also the coefficients K and Ct, by which to unify the safe eustress periods for the samples and to be able to make comparisons. Three indicators for the assessment of eustress were also introduced and defined - frequency per 100 years (F), duration (D) and depth (A). 5-level scales have been developed to evaluate these indicators for different types of trees. This approach to stress analysis is inherently holistic, as the ongoing physiological processes (mechanisms) leading to a reduction in radial growth are not considered in detail, but the end result – the formed annual ring – is analyzed. To form the samples in the conducted dendroecological studies, the dominant tree species of the first class of Kraft for the respective habitat were probed to minimize the coenotic influences on the radial growth and to enhance the climatic signal to investigate the influence mainly of the variation of temperatures and precipitation on increases. In the previous studies, the influence of climate on It is through regression analysis of the series of monthly and annual precipitation sums and the average annual and monthly temperatures and calculation of the corresponding indices. Due to the impossibility of obtaining trends that sufficiently describe the dynamics of these climate indicators, obtaining the models of influence on growth are not sufficiently accurate. Another approach was developed in Lyubenova's dendroecological research – identification of climatic types of years for the growth period and search for the prevailing types corresponding to the appearance of eustress. Due to a delay in the response of tree species to impact, in the latest version of the analysis, the "pattern analysis" is developed - the analysis of the climatic type and of two years preceding the occurrence of eustress. For the development of this new dendroecological analysis approach, the "climatic year type" (a calendar year with precipitation and/or temperatures within or outside the climatic norms for precipitation and temperature) was statistically defined, considering the types: HD, CD, ND, HW , CW, NW, NN (H- warm, D – dry, C- cold, W – wet, N – normal). Climatic norms are defined statistically as the average value of precipitation or annual temperatures for 30-year periods together with the confidence interval of these values. The meta-analyses of our own dendrochronological data for different species in Bulgaria and those from the international dendrochronological database prove the applicability of the approach for identifying eustress periods in radial growth, its characteristics and taking into account the influence of climatic types of years (CTs). A study of the relationship of eustress with the standardized precipitation index (SPI) was made and it was confirmed that in the specific case CTs better describe eustress. Greater adequacy of the analyzes would be achieved in determining the biological year and its climatic type. It is specific for each tree species and depends on its ecological features and habitat conditions, includes the months in which there is active life activity and environmental factors significantly influence the vital functions, as well as the months of the previous year, the regimes of which have a significant influence on

the current increment. The period of deep dormancy in deciduous trees is excluded from the length of the year. For this purpose, however, systematic and organized studies by region and species are needed on the duration of the growing season, the periods of seed formation and the dynamics of climatic factors. A significant part of researches has been conducted by the international projects, and the results have been published in one monograph, 2 books, 2 book chapters, 12 in journals with an impact factor, 6 in non-indexed journals and 5 reports of proceedings.

To implement the analyzes in co-authorship, the SP-PAM software is being developed, so far in 2 versions (manual C7 and publications E12 and E48) and a classification-oriented database of dendrochronological and climatic data has been created for conducting meta-analyses.

B1. Scientific contributions

8. Development of the scientific direction - "dendrochronology", the sub-direction - "dendroecology" at Sofia University.

Over 20 developments have been published; under the scientific supervision of Assoc. M. Lyubenova, the following were defended respectively: the first thesis at Sofia University and the first dissertation in the field of dendroecology, and so far there are more than 10 diploma theses with such topics. In the next dissertation were also applied dendroecological methods for modeling the radial growth and assessment of the tree layers state in habitat 91M0 of the Western Stara Planina and ForeBalkan Nature Reserve.

9. Dendro-ecological studies of tree species of conservation importance in protected territories and zones are one of the first in the country, and an attempt was made to assess the condition of the tree layers and the factors determining it.

9.1. *Taxus baccata* L. - it was found that the dynamics of the growth index is described by an exponential trend, 93% is determined by the rainfall regime and the most important are the rainfall amounts in October and December of the previous year and January and June of the current year. The species has overcome the two established stress periods and the site is in a development stage.

9.2. *Juniperus excelsa* M.B. – it was established pronounced decline of the communities; extremely low radial increment; damage to the tree stand that increases with age; the dynamics of the growth index is described by polynomials of different degrees; two long stressful periods and several stressful years related to the rainfall-temperature regime, the attack by the juniper moth and the influence of anthropogenic factors.

9.3. *Pinus heldreichii* Christ. и *P. peuce* Griseb.

It was found that the growth curve for both species is of a polynomial type; available extended stress periods with a maximum duration of 35 and 54 years; in the case of Bosnian pine, the main influencing factor on radial growth is temperature, especially in August; in the case of Balkan pine, the main factor is the precipitation in November of the previous year and March of the current year.

9.4. *Castanea sativa* Mill.

The communities of the species in the Berkovitsa Balkan and Belasitsa Mountain were studied. A sustainable decline has been established, which is limited by a complex of environmental factors. For the communities from Berkovitsa Balkan, 4 types of biological curves were established for the different groups of trees, showing the heterogeneity of the sample in terms of the carried ecological signal. Five stress periods with a large average duration are outlined. Statistically, the importance of precipitation amounts, especially those in October of the previous year, for the formation of growth has been proven. In later parallel analyzes with chestnut chronologies from Belasitsa Balkan and chestnut chronologies from the "Sokolata" reserve, an analogy between the rows of chestnut and oak indices for the last 50 years was established, and the months in which the hygrothermal regime was limiting for the formation of the radial increment for chestnut from both sites and oak: trees respond positively to rising temperatures in June and August, but negatively to excessively warm September and cold April; the negative impact of excessive rainfall in the previous September and of the current year - May, June and July, and a positive impact on the increase in rainfall in February. For the first time, preliminary results have been published regarding the degree of influence of *Loranthus europaeus* Jacq. on the growth.

9.5. *Quercus frainetto* Ten. in the "Sokolata" reserve - one of the first dendroecological studies of the species for the Sokolata reserve, where it was found: a significant correlation between the series of indexes for the annual ring and late wood; the published stress periods for the same species in Slovakia are confirmed; the limiting influence of the climatic regime in the formation of growth - the strongest influence is the temperatures in the middle of the growing season and the precipitation at its end, and for the formation of early wood - the temperatures at the beginning of the growing season.

9.6. *Picea abies* Karst. and *Fagus sylvatica* L. in the Chuprene Biosphere Reserve - It was found that the biological curves that best describe the dynamics of the growth index are of the third-degree polynomial type and secondly - the exponential type. The dynamics of the indices show that the vegetation is exposed to a series of weaker or stronger stress periods that almost completely overlap with periods of drought - the climate with its two components - precipitation and temperature is one of the main reasons for the appearance and development of degradation in the studied communities.

9.7. Collection and study of chronologies of *Pinus nigra* Arn. from Gabra maintained reserve.

10. Dendroecological studies of significant tree species in park areas have been published.

10.1. *Quercus rubra* L. and *Q. robur* L. from 4 park areas.

It was found that the main stress periods were around the years: 1945, 1950-1960, 1987-1990, 1996-2000. The critical months in terms of climatic factors for the studied species are: rainfall in April, May, June and last year's temperatures in October, November and December. In the study of early and late wood, a difference was found in the indicator value of the rows in terms of sensitivity and influencing factors.

10.2. *Pinus sylvestris L. u P. nigra Arn.*, mainly in the Sofia region.

It was found that the change in the indices of the average homogeneous rows for the two species and the studied period (1895-2000) is described well enough by a polynomial of the third degree; the obtained homogeneous series of indices for the two species (of the annual ring, early and late wood) have a high sensitivity (over 25%), i.e. are suitable for bioindication purposes; the similarity between the index rows of the annual ring and those of the early wood is greatest; published stress periods for Scots pine were confirmed and a set of stress periods for Scots pine with different frequency and duration were established; a tendency to increase the values of the growth index for the black pine was found after 1995; important factors for radial growth are the growth potential of the previous year and the precipitation-temperature regime.

11. An original holistic approach in dendroecology was developed to identify and evaluate periods of reduced radial tree growth (eustress periods) based on the growth index.

11.1. Eustress and the three parameters for its assessment are theoretically and statistically defined - frequency, duration, depth. The terms "climatic norm" and "climatic year" are theoretically and statistically defined for the purposes of denro-ecological analysis.

11.2. For the first time, a formal and recursively computable eustress nomenclature has been established. On the basis of the developed 5-point scale for comparative assessment of eustress, the potential risk to the forest health and its sustainable existence in the occupied territory can be assessed.

12. 12. For the first time in dendroecology, comparative analyzes of eustress have been published using a large set of climatic and dendrochronological data and their characterizing descriptions (meta-data).

12.1. Comparative dendroecological studies of meta-data for *P. sylvestris* L.

Included in the analysis are 1007 chronologies from 28 localities in the Southern and Northern parts of its range - Spain and Scandinavia.

Summary results. Stress periods common to these remote geographical locations were established: 1901-1911; 1917-1922; 1936-1942; 1949-1950 and 1961-1969; in the two studied areas, eustress (EC) is provoked by hot and dry years; in second place are the cold and dry years in Scandinavia, while in Spain it is the cold - wet and dry years; in Scandinavia, a greater number of localities have an average frequency of eustress of 3 and 4 degrees, and the depth is of the 3rd degree - the growth is characterized by the frequent and very frequent occurrence of deep EU; in Spanish localities, EU appears very rarely or rarely for 68% of localities; for 10 of the studied sites in Scandinavia and only two of them in Spain, the combination of frequent or very frequent occurrence of deep EU may pose a risk to Scots pine ecosystems.

12.2. Comparative dendroecological studies of meta-data for *P. nigra* Arn.: 682 chronologies from 29 sites in Europe.

Summary results. Radial growth and the number of identified stress years varied a little among the locations studied, but differences in EU characteristics between locations were significant; the average values of the duration and frequency of stress periods, of the coefficient K and the depth of stress periods are identical or close to the published values for Hungarian oak; changes in EU characteristics (frequency with changes in altitude, duration with changes in latitude and depth with changes in average annual precipitation) are described by a sixth degree polynomial, R2 = 0.3 - 0.4; in 48.3% of the locations a moderate risk was found, for about 41.4% - the risk was weak and only for 10.3% - the risk was significant. It has also been found that most of the climate stress is caused by very dry or very wet years, especially when combined with a cold or warm regime; the buffer capabilities of forest communities are important, i.e. their ability to modify the regional climate, and the sequence of climate types (CT) in previous years. In parallel, the relationship between EU and SPI (Standardized Precipitation Index) was investigated and it was found that, in cases where there is no large difference in temperature and precipitation values across sites, the use of STI to study the relationship between climate change and forest functioning ecosystems is more applicable.

12.3 Comparative dendroecological studies of meta-data for *F. sylvatica* L.: 325 chronologies from 10 sites in Europe.

Summary results. An inverse correlation between It and altitude was established, which can be described by linear regression and a power function; inverse linear regression between It and negative precipitation deviation from climatic norms for precipitation (dP) at 60% of the locations studied. There are differences between the climatic type of the calendar and the biological climatic years determined for the same locality, which are significantly manifested in the small and large altitudes. 25 total stress years were found for 50% of the locations; warm and dry years are the predominant provocateurs for the emergence

of EU, and with high altitude predominant unfavorable years are wet and dry years. The studied locations form 5 groups according to the EU assessment of the three indicators – depth, frequency and duration. The forests in three of them had the capacity to buffer the adverse climatic influence, but for two of the locations there was a risk for the tree stand.

12.4. Comparative dendroecological studies have been made on *Quercus frainetto* Ten., *Q. cerris* L. *and Q. dalechampii* Ten., respectively for 250, 161 and 130 years: 136 chronologies from 6 localities in the Sofia region and from the Sokolata reserve; also for the communities of Hungarian oak (60 chronologies, age 42-77 years) and Turkish oak (48 chronologies) in 5 localities of the "Western Stara Planina and ForeBalkan" Protected Zone.

Summary results. Eustress periods - 57, 30 and 13 with coverage above 50% were obtained for three species, respectively. It cannot be explicitly stated that there has been an increase in the number of eustress periods (ESPs) in Hungarian oak and Turkish oak in the studied regions during the last 57 years. The influence of temperature-precipitation regime was better expressed for the radial growth of Hungarian oak and Turkish oak. Aaverage frequencies of ESPs over the past 57 years were as follows: 3.3 for Turkish oak, 3.7 for Hungarian oak and 4.4 for Dalechamps oak. Respectively, from 62.5% to 56.52% and 33.33% of warm and dry CTs and from 33.33% to 40.91% and 35.29% of cold and humid CTs caused a decrease in radial growth during the last 99 years. The common stress years found were as follows: 1968, 1979, 1985 and 1987, and 1945, 1950 and 1968; cardinality and coverage were 7 and 100%, respectively. Some of the stressful years were also confirmed in the protected area. In both studies, Hungarian oak emerges as a more sensitive species compared to the Turkish oak, when the regimes deviate from the climatic norms. It also showed higher values for the number of ESPs and its characteristics. The stress was also provoked by the sudden change of climate types in the previous two years. For the half of the investigated localities, there was no risk for the existence of Hungarian oak - Turkish oak forests in the zone. In general, more stress periods were found and the stress was prolonged and very deep ones compared to the beech communities of the zone and the Turkish sites of Turkish oak.

12.5. Comparative dendroecological studies of meta-data *for Quercus rubra* L. and *Q. robur* L. in America and Europe: 428 chronologies from 14 localities.

Summary results. The obtained values for the relative number of ESPs, its duration and frequency for both species were close to the published values for Turkish oak and Hungarian oak from Bulgarian and Turkish localities, despite the geographical differences. The obtained average values for depth of eustress for both species were lower than those for Turkish oak and Hungarian oak from Bulgarian localities. By means of the mentioned indicators, no risk was indicated for two species in the studied localities. The established general stress years have been published as unfavorable for the condition in other deciduous trees as well. The years 1936 and 1966 were the most common stress years for all American oak sites

studied, and five years: 1941, 1942, 1965, 1966, and 1970, were stressful for both oak species from different geographic regions in their study sites.

12.6. Comparative dendroecological studies of meta-data *for Quercus petraea* (Matt.) Liebl. in Europe: 255 chronologies from 13 sites.

Summary results. An average of 42 ESPs were found. The evaluation of ESPs characteristics showed the existence of a risk for the species communities in three of studied localities. Predominant among the total number of unfavorable years are the hot and dry (HD) cold and dry (CD) climate type, etc.

B2. Applied Contributions

8. For the first time, in co-authorship, a reconstruction of the precipitation in South-Western Bulgaria for 200 years was made, using chronologies of Hungarian oak.

9. The published dendroecological studies on tree species and their communities are applicable in the preparation of protected areas Management Plans, for the management of the park areas and for the purposes of biological monitoring.

10. Published dendroecological meta-data studies are applicable to characterizing the resilience of the species' communities in parts of its range and delineating possible trends of change, which is important for the changes in vegetation cover simulating.

11. An original application was created in co-authorship - SP-PAM, developed in 2 versions, for analysis of meta-data (dendrochronological and climatic), identification and assessment of periods of reduced growth (eustress periods), appearance of functional types of trees and their verification as well as forest ecological monitoring and risk assessment.

The main functions of proposed software, called SP-PAM, are: summarizing the stress periods of a random sample; statistical analysis of the total periods of eustress and its characteristics; eustress categorization and risk assessment. These analyzes can facilitate forest monitoring and determining trends in forest ecosystem development. The information is applicable for assessment, forecast and ecological management of forest resources in forestry practice for sustainable development of the regions.

12. Participation in the creation and maintenance of the site www.e-ecology.org, on which the online results of SP-PAM application are displayed and they can be freely used by users.

13. Participation in the maintenance and filling of a classification-oriented database of dendrochronological and climatic data, which can be used for various analyzes and the preparation of ball scales.

C. GROUP OF CONTRIBUTIONS RELATED TO APPLICATION OF MODERN INFORMATION TECHNOLOGIES IN FUNCTIONAL ECOLOGY AND MODELING OF ECOLOGICAL SYSTEMS (B1, B2; E23, 25, 30, 33, 37, 45, 52, 55, 63, 71; F2 32, 32 , 46; G1 – 9, 12, 19, G2 - 14) or 2 monographs, 10 publications with an impact factor and impact rank, 4 publications in non-indexed journals, 4 publications in collections of reports, etc. – 5 scientific and applied contributions.

Today, it is especially necessary that knowledge about the structure and functioning of ecosystems be rethought and summarized with the means of information technologies for the following reasons: presence of a huge flow of data and information obtained through modern means of monitoring natural and cultural ecosystems and globalization of ecological knowledge; rapid development of information technologies; there is an urgent need to develop ecological data bases, unifying information in a given direction and facilitating its practical use for developing models for rapid diagnosis of impairments, forecasting the effects of existing regional and global geopolitics to limit and stop negative effects, ecological management for sustainable existence of the biosphere. However, there are a number of limitations to the creation of working ecosystem models: ecosystems are practically almost always out of equilibrium, i.e. it is difficult to define the key indicators of "normal health status"; a large number of ecosystem characteristics and parameters were proposed, with different developments optionally characterizing a different number of them, sometimes using different methods; most of the existing reasons - relationships related to the functioning of ecosystems are not sufficiently well studied; there is no developed representative functional classification of ecosystem types - similar in structure, biological cycle type and energy flow. Due to the lack of a system of standardized indicators and unified methods for ecosystem modeling, for ecosystem health assessment, for ecosystem level monitoring, the available information is characterized by a limited set of measurements and a large set of indicators; incompleteness - lack of repeatability of measurements of a number of parameters in space or time and taking parameters under non-standardized environmental conditions. The application of mathematical statistics in the processing of these data very often does not give reliable results. The need to summarize the accumulated ecological information leads to the increasingly systematic introduction of new information technologies for generalization, systematization and research of existing relationships and dependencies, as well as for deriving ecological theoretical and practical conclusions. The development of different generations of models and the search for dynamic ecosystem indicators for simulating ecological effects are also included in this direction. In other words, the scientific direction deals with the active search for modern information technologies to solve environmental problems. With the active participation of Associate Professor M. Lyubenova, the site www.e-esologu.org was created for the exchange and promotion of interdisciplinary knowledge in the field of information technology and ecology. To develop the created intermediate direction, modern specialists familiar with information technologies and existing ecological models, as well as having knowledge in the field of ecology and environmental protection, are needed. With the active participation of Associate Professor M. Lyubenova, the master's program "Information Technologies in Ecology" was created at the Faculty of Science and Mathematics of SouthWestern University, due to the appropriate structure and staffing of the university.

The modern approach to the study of ecological systems requires the integration of various research methods, modern aero- and geo-information technologies and new information technologies (IT).

C1. Scientific contributions

13. Participation in the development of the new scientific direction in ecology "e-ecology" (modern information technologies in ecology), which is the Bulgarian contribution to the international COST action ES 0805 TERRABITES.

14. Participation in the development of concepts for the application of new information technologies in ecology.

14.1. Involved in developing for the first time the concept of a classification-oriented ecological database.

An original concept for a classification-oriented database (CODB) was developed in co-authorship. The main characteristic of the proposed classification base was that it allowed easy modeling of material or ideal objects, and the relationships between them were described by means of levels of generality (from more general to more specific category) and levels of content (aggregation). Thus, for each unit it was known where it was in the hierarchy of a community of categories, as well as in data aggregates (similar to taxonomic classifications in biology). In addition, space-time information was necessarily stored for each unit. The CODB allowed the establishment of a connection between the numerous available bases for biomass, production, circulation of substances, etc., greater operability, combinability and increased possibilities for the optimal categorization of connections and regularities between the available data, facilitating modeling and forecasting. The developed CODB has been used by the SP-PAM application as well as for projects in the field of energy efficiency (in industry). The research was done on an international and national projects and was published in a journals with an impact factor.

14.2. Participated in the development for the first time of the concept of the application of the ontology and the semantic web for the exchange of environmental knowledge.

A co-authored approach was developed to use the Web Ontology Language (OWL) for the formal representation of complex object systems such as macrobiological systems. The approach was illustrated by a formal description in OWL categories of a simplified principle model of ecological structure. The possibility of presenting complex ecological systems in a machine-readable format was illustrated. The research was carried out on an international and national projects and was published in journals with an impact factor.

15. Contributions related to the modeling of ecological systems.

15. 1. In co-authorship, a mechanistic formal model of chestnut ecosystems was developed for the first time in the "Belasitsa" Natural Park .

Summary results: For the first time, the ecosystem approach and the existing eight main ecosystem characteristics have been creatively applied for ecosystem diagnostics. A system of indicators for modeling of chestnut ecosystems has been developed - a basis for the development of mechanistic and formal models. The existing database of these indicators has been completed. The requirements for the ecosystem indicators were indicated: to reflect the features of elements key to the ecosystem; to reflect functions important to the ecosystem; to reflect integral indicators; to have standardized methods of reporting and, where possible, developed techniques for repeated observations. An assessment of the influencing socio-economic factors on chestnut ecosystems was also made and the DPSIR logical framework for their sustainable management was applied. The research was funded by an international and national projects and was summarized in a monographic work.

15. 2. For the first time in co-authorship neural networks (NN) and self-organizing maps (SOM) were applied to model xerothermic oak ecosystems, expanding the application of this IT in the field of ecology.

Advantages of NN: allows avoiding the existing shortcomings of ecological data for macrobiological systems. Research has been done on an international and national project and has been reported at international forums.

15. 3. Original results and assessments of the health status of spruce and beech ecosystems from the Chuprene Biosphere Reserve have been published (in co-authorship) with the integral use of the ecological approach and geographic information systems.

Summary results: Based on the available information and the research done, layers were created of: forest subdivisions with stand characteristics (defoliation, age, composition, etc.), relief layers - elevation, slope, exposure, soil characteristics layers and others. The degree of damage was analyzed depending on the different factors and the distribution of healthy stands and those with different degrees of damage in relation to these factors. Conclusions were made about the dynamics of spruce and beech vegetation in the reserve and successional changes. The research was done as part of a university project and was published in a international and Bulgarian journal and in a collection of scientific forums.

16. Contributions related to spatial modeling through the combined use of aerospace technologies and GIS to study forest vegetation dynamics.

Summary results: In the co-authorship, an integral approach for using geographic information systems and aerospace information technologies for spatial modeling of the change in the areal distribution of forest habitats in relation to orographic factors - altitude, exposure and slope of the terrain - has been applied. Modeling these spatial dynamics under corresponding climate change makes it possible to predict the impact of climate on the composition and distribution of forest vegetation in a given area. The researches were by international and national projects and has been published in journals with an impact factor, a Bulgarian journal and has been reported on international forums.

16.1. Co-authored pilot original studies on the spatial dynamics of forest vegetation in Belasitsa Natural Park were published.

Summary results: As a result of the modeling, changes in the spatial distribution of forest communities in the natural park over a 23-year period (since 1977) were found, resulting in: a decrease in the area of mixed forests on eastern and western exposure by 9% and 33% respectively, due to the conversion of mixed forests from over 1200 m altitude in beech or in chestnut forests at altitude below 1200 m; also displacement of the mixed acacia-chestnut forests at an altitude below 900 m. Areas occupied by chestnut communities expanded by 28%, 15% and 5% in western exposures, respectively, for the altitude range 874-376 m and for the altitude range 1271-389 m. Areas with beech communities on western exposures expanded by about 5% and high altitude (1435-771 m) areas increased by more than 2%. The lower distribution limit of chestnut forests has decreased, and the upper limit at some altitude ranges has increased. The majority of forest communities in the mountains were distributed at a slope of 15-23 °. This distribution also changed over a 23-year period – the largest areas occupied by beech forests are at a slope of 0 - 15 °. These results prove the initial hypothesis that under the influence of changes in environmental factors (mainly climatic), corresponding changes in forest vegetation can be expressed not only by changing in the species composition and the size of the occupied area, but also by changing in the spatial distribution of communities in relation to topography factors.

16.2. Co-authored pilot original studies on the spatial dynamics of forest vegetation in the Eastern Rhodopes have been published.

Summary results. An increase in the areas occupied by broad-leaved vegetation and a decrease in the areas occupied by coniferous vegetation were found over a 20-year period. For the same period, no significant changes were found in the dynamics of the temperature-precipitation regime. This increase is probably due to reforestation of the deforested areas in the deciduous forest belt. An increase in NDVI values was also found for all forest classes.

16.3. За първи път са публикувани в съавторство оригинални пространствени модели на ксеротермни дъбови гори в ЗЗ „Западна Стара планина и Предбалкан“ и оценка на състоянието.

A combined survey method was applied and the status (via the status vector) and change of the communities were assessed.

Summary results. Spatial models were created for the distribution of xerothermic oak ecosystems in PZ in 1977, 1992 and 2007. The change of the occupied territories in relation to altitude, exposure, slope, soil type and soil-forming rock was studied as a response to climatic fluctuations (the de Marton index was used). The ecological status of communities is determined by calculating the status vector and the output factors with the greatest weight for the established status are indicated. The comparative

analysis of the spatial and ecological state of the oak forest vegetation is the result of the application of combined processing of: satellite information, orthophoto, GPS and ground data using space technologies and modeling in GIS environment. The created spatial models can be used in the monitoring of forest ecosystems, for conservation purposes, for sustainable management of forest territories, as well as for the study of xerothermic oak vegetation in other regions and protected areas.

17. Contributions related to the development of dynamic global vegetation models, DGVMs.

17. 1. The ecological foundations of ecosystem-level modeling are discussed as a basis for the development of regional and global models.

Summary results. Macrobiological systems are considered as ACS or CAS - "Adaptive complex system", each of them being a subsystem in the hierarchical structure of living matter, characterized by its own particularities of "behavior" in the changing environment. A system of modeling indicators based on those used and published in the modeling of chestnut and beech ecosystems is commented.

17. 2. Contributions related to the emergence of new generation of functional tree types based on periods of eustress for the development of DGVMs.

Summary results. The definition of new PFTs related to the relationship between the dynamics of biological indicators and the dynamics of ecological factors over time (allowing long-lived and static tree species), as well as reflecting the functioning of forests (radial growth can be used as an indicator) was extremely necessary for the further development of DGVMs to obtain better simulations of vegetation cover changes. No classification of functional types has been developed so far, which includes an indicator with known dynamics over a long period of time that makes it possible to make predictions. New possibilities for building original PFT classifications of trees are proposed according to the features of periods with reduced stem growth – frequency, duration and depth and according to the prevailing type of unfavorable climatic year initiating the reduced growth. A specific terminology related to the general and statistical characteristics of these periods and years is introduced, as well as a 5-point scale for evaluation and comparison. For this purpose, 1674 dendrochronological series of 9 conifer and broad-leaved species from 102 localities were processed, as well as the data on rainfall and temperatures for each locality for the period 1901 - 2009, and the properties of the growth index were used as a classification indicator. The research was carried out under an international and national projects and was summarized in a monographic work.

C2. Applied Contributions

14. The proposed approaches, indicators and models can be applied in modelling, biological monitoring and in the creation of "Decision Support Systems", DSS, for the purposes of adaptive management of forest vegetation for sustainable development.

II. A GROUP OF CONTRIBUTIONS FROM BIODIVERSITY RESEARCH AND ITS CONSERVATION SIGNIFICANCE: POPULATION, FLORISTIC, PHYTOCENOTIC, HABITAT AND LANDSCAPE (C12; D21; E11, E15, E18, E27, E28, E31, E34, E37, E53, E58, E68, E7; F2, F3, F15, F20,F25,F26, F27, F29, F30, F47, F48, F49, F51; G1 – 1, 3, 13, 14, 15, G2 – 1, 9, 15, 16, 17, 18**).** In the scientific publications, 3 scientific and 4 applied contributions were formed.

In almost all functional studies from the first thematic direction (I), a phytocenotic characterization of the communities - the object of the study, including orographic factors, species composition, assessment of abundance by floors, dominant structure, some of the taxation indicators, etc. were also characterized. In some of the publications, elements of flora analysis, among other indicators, were also used in the assessment of the condition and the changes occurring. This combination of structural and functional indicators determines greater correctness, when applying the methods, when performing the analyses, also when evaluating the results obtained and the assessments given for the state of the studied plant communities. However, the emphasis is placed on the functioning and not on the structure of phytocenoses, wherefore these publications are referred to item I. Functional phytocenology. The author has also carried out targeted research on the species composition and structure of chestnut, xerothermic oak, beech and other habitats (mainly under Natura 2000 projects), a large part of this research has not yet been published. They have found their practical implementation in the updating of habitat forms and the evaluation of the favorable nature-protection status of habitats in the protected zones under the Natura-2000 program.

II.1. Scientific contributions

18. Co-published original phytosociological and phytocenological studies of modern forest vegetation.

18. 1. Phytocenological and phytosociological studies of the chestnut forests in Belasitsa Natural Park, which were among the first in the country.

Summary. During the phytocenological studies (2004), 4 associations were established, and during the phytosociological studies (2007), on the basis of the existing information, the syntaxonomic decision was made that the described forest communities can be referred to the class *Quercetea robori-petraeae*, order *Quercetalia robori-petraeae*, union *Quercion robori-petraeae*, assoc. *Castanetum sativae-macedonicum* Nikolovski (1951) and subsoc. *fagetosum* Em 60. In the last phytosociological studies, based on more descriptions, analysis of paleoecological data and established proximity of the studied vegetation to that in the northern parts of Greece, a revision was made and a new phytosociological decision was published - the chestnut vegetation is referred to assoc. *Tilio tomentosae-Castanetum sativae*. The studies were carried out under 2 international and one national projects and were published in a journal with IF, an

international journal and a collection of reports from an international forums. The sociological studies of chestnut forests in Belasitsa Natural Park were among the first ones in the country.

18.2. Phytosociological studies of the communities of *Quercus frainetto* Ten., *Q. cerris* L., *Q. dalechampii* Ten. in Bulgaria, which are among the first in the country. Structural studies of these communities were also carried out in the "Western Stara Planina and ForeBalkan" PZ.

Summary. The study represented a first attempt to generalize descriptions of xerothermic oak communities in the hilly plains and foothills belt and xero-mesophytic oak communities in the lower mountain belt. These forest communities were an element of the potential vegetation and were highly anthropogenically influenced. The descriptions have been collected since 1980. The studied vegetation was referred to the unions: *Quercion confertae* (Horvat, 1949) and *Quercion petraeae* (Zolyomi et Jakucs in Soo, 1963). The researches has been published in indexed journals and proceedings of scientific forums.

18. 3. For the first time, one of the largest find of *Taxus baccata* L. in the"Central Balkan" National Park was described and phytocenological and floristic studies were carried out.

Summary results. The described communities with dominance and participation of common yew occupy an area of over 138.2 ha; 61 species of higher plants have been identified, incl. a Balkan endemic - *Moeringia pendilla* (WK) Fenze. The species composition is dominated by the perennial biological type, the Euro-Asian floral elements, and from the life forms of plants – cryptophytes and hemicryptophytes. Based on the calculation of the similarity coefficient between the described phytocoenoses, the vegetation is assigned to the associations: *Fagus sylvatica+Taxus baccata-Carex digittata+Sesleria latifolia* and *Fagus sylvatica+Taxus baccata*-subnudum.

19. The original floristic studies were published in co-authorship

19.1. The floral analysis of xerothermic forest ecosystems (*Quercus cerris - Q. frainetto*) in Bulgaria were among the few modern floristic studies of these communities in the country.

Summary. On the basis of more than 100 phytocenological descriptions, 598 species of higher plants (271 genera and 67 families) and 24 species of bryophytes were identified throughout the country, which confirms the great species richness of these forests. The participation of Euro-Asian, Euro-Mediterranean, Sub-Mediterranean, Euro-Siberian and European flora elements is greater. Among the life forms, hemicryptophytes clearly predominate. The research has been published in an international journals.

19.2. Original floristic research in protected areas and zones.

19.2.1. Floral analysis of chestnut (*Castanea sativa* Mill.) coenoses in Belasitsa Natural Park and Western Stara Planina and ForBalkan PZ, which were among the few modern floristic studies of these communities in Bulgaria.

Summary: From 20 transects, 270 species of higher plants belonging to 189 genera and 62 families were identified in the chestnut vegetation. The participation of Mediterranean, Euro-Asian, Euro-Mediterranean and Sub-Mediterranean flora elements is greater, respectively. Of the life forms, hemicryptophytes clearly predominate, and phanerophytes have a large share. Comparing the data obtained with data from research in 1921 shows the following trends: decreasing participation of phanerophytes and increasing that of hemicryptophytes and cryptophytes in the flora complex; also reducing the participation of boreal elements and increasing - of ruderal plants. In the floristic composition of the chestnut forests in the Berkovitsa Balkan, 139 species of higher plants have been established; these forests rank second in terms of species richness after the communities in Belasitsa. Euro-Asian floral elements and hemicryptophytes predominate in the floristic composition. The strongly pronounced tendency of the degradation of chestnut forests and the gradual successional replacement of chestnut by other broad-leaved species was confirmed by the established high percentage participation of phanerophytes in the biological spectrum and the graphical model of the distribution of chestnut in the Berkitsa Balkan. The research is by a bilateral and national projects and has been published in Bulgarian journals.

19.2.2. „Kamenshtitsa“ Reserve, Central Stara Planina Mountains

Summary. A floral analysis was made of the forest (f. Ouerceta dalechampii and f. Fageta sylvaticae) and grass vegetation in the reserve. 114 (90 genera and 41 families) and 129 (96 genera and 38 families) species of higher plants were found in the forest and grassland communities, respectively. Of the flora elements predominant for forest vegetation were: Euro-Asian, sub-boreal, Euro-Mediterranean and Euro-Siberian, and for grass vegetation – sub-boreal, sub-Mediterranean, Euro-Mediterranean and boreal elements. Of the life forms, hemicryptophytes and cryptophytes predominated. The research was funded by a university project and was published in a proceeding of international forum.

19.2.3. Western Stara Planina and Fore-Balkan PZ, Turkish oak-Hungarian oak communities.

Summary. During the inventory, 100 species of higher plants were found, belonging to 80 genera and 40 families; in the biological spectrum, hemicryptophytes predominated, and from the floral elements - Euro-Asian and sub-Mediterranean, followed by European, Euro-Mediterranean and sub-boreal elements. The research was funded by a national project and published in a journal with IF.

19.2.4. The joint studies of the vegetation of the reserves: "Terfeno branishte", "Gornata koria", "Chamlaka" and "Vasil Kolarov" have been published, which are one of the first investigations of these reserves and they were the basis of the later studies.

19.3. New horological data for 19 species of higher plants, of which 3 are included in the Red Book of Bulgaria for the floristic region - the valley of the Mesta River.

The research is part of an operational program and a national project (Natura-2000 in Bulgaria) and has been published in a journal with IF.

20. Original research on the vegetation and biotype diversity of the spruce population in the Chuprene Biosphere Reserve has been published.

Summary. During the ecological studies in the Chuprene Biosphere Reserve, a great diversity of forms was found in the spruce population (according to the length and width of the seeds, the length and width of the cone, the length of the needles; striation and color of the stem bark, height and branching of the crown) . In the "Veternika" locality, a hybrid form was found, which, probably during the nest germination of the seeds and the development of the young plants, gives several equally viable stems, emerging from one place (formation of several stems from one seed nest), but combining different forms, which also different from the surrounding trees. Through genetic research, a highly pronounced local polymorphism was proven, which, together with the great variety of forms in relation to the various signs, suggests that the studied object is a form-forming locus. For the first time, a discriminant analysis of the marks in the different forms was made to search for a connection between them and their signs, and the degree of "attachment" of the signs to the individual forms was investigated. The research was done as part of a university project and was published in the proceedings of an international forum.

II. 2. Applied Contributions

15. The results of the biodiversity research have served to complete the national and Balkan phytocenological database.

16. Contributions from collaborative developments related to habitat 9260 Chestnut forests.

Summary. A series of developments have been published for various scientific and social circles. In these studies, information on the distribution and ecological characteristics of 9260 in Belasitsa and in the country has been synthesized and different types of management have been commented on - ecological, adaptive and alternative (the DPSIR logical framework); the generalization of the information about the habitat in other parts of the country also served to include it in the Red Book of the Republic of Bulgaria and to develop the parameters for determining a favorable nature protection status.

17. Contributions from collaborative studies on the diversity of habitat types and their conservation significance.

17.1. Beech habitats in the Central and Western Balkan Mountains.

Summary. A comparative analysis of the species composition of habitats 9110 and 9130 in Central Balkan with other regions of the country was made; a comparative phytosociological analysis was made between habitats 9110, 9130 and 9150 in the Western Balkans in order to better differentiate Cephalantero-Fagion from other beech habitats in the beech belt of the mountain.

17.2. Habitat 91M0 in 4 protected zones

Summary. An analysis of the differences in the composition and structure of the communities in the "Western Stara Planina and Fore-Balkan" protected zone, the "Central Balkan - buffer" protected zone, the "Dolna Mesta" protected zone and the "Western Rhodopes" protected zone was made on the basis of geophysical and phytocenological descriptions. The significance was discussed of habitat 91M0 for the Western Stara Planina and Fore-Balkan PZ and its economic importance for the region based on a group of indicators.

17.3. Habitat diversity along the valley of the Mesta River and in the Western Stara Planina and Fore-Balkan" PZ.

Summary. The geographical area under discussion (the right valley slope of the Dospat River) falled between three protected areas, two on Bulgarian and one on Greek territory - BG 0001030 "Western Rhodopes", BG 0000220 "Dolna Mesta" and GR 1140008 "Mesta River Valley". The right valley slope of the Dospat River was located on Bulgarian territory and was mostly rocky, occupied by habitat 8210, habitats 91HO in the north and 91AA in the south were also represented. The authors proposed the inclusion of the section along the Dospat River in the "Western Rhodope" PZ, which means connecting the area with the "Dolna Mesta" PZ and uniting it with the Greek protected zones. The integration of these protected zones will improve the quality and quantity of the ecosystem (landscape) services they provide. The diversity of habitats in the "Western Stara Planina and Fore-Balkan" PZ was examined and evaluated.

18. Landscape diversity along the Kamchia River valley and conservation significance.

Summary. The landscape diversity along the Kamchia river valley has been described and mapped. Tendencies of xerophytization of the longose vegetation in the valley and development of new types of landscapes have been established. Of the landscapes - genus Longosa, 5 species are described, some of which involve *Quercus cerris* L. These landscapes refer to habitats 91EO, derived shrub and grass landscapes are also available. The unique complex vegetation (habitat 91F0) is highly sensitive to deterioration of the water regime. The trends of xerophytization are a serious threat not only to its existence, but also to the preservation of the stability of the natural complexes in the valley.

III. GROUP OF CONTRIBUTIONS FROM RESEARCH ON ELEMENTAL COMPOSITION OF PHYTOMASS, POLLUTION, PHYTOMONITORING AND ECOTOXICOLOGY (B4; C11аб;, D22, D33; E4, E8, E10, E12, E13-14, E17, E19, E21, E26, E29, E32, E47, E52, E56, E61, E62, E64, E66, E69, E72; F13,F14, F17, F21, F30, F31, F40, F43, F45, F50, F52; G1 – 6, 18; G2 8) – 4 applied contributions.

In a number of studies, data on the elemental composition and contamination of the phytomass have been published. The emphasis in these publications is on the study of the peculiarities of the biological cycle, and therefore they are considered in I. Functional Phytocenology. M. Ljubenova has some research (in co-authorship) on ecotoxicological assessment, agroecosystems pollution with

wastewater, also related to air pollution with ozone, impact on vegetation and monitoring of the pollution degree. In this thematic direction, the contributions from these studies will be commented on.

Applied Contributions

19. The data on the elemental composition and pollution of the phytomass served to fill the international database TRY, can also be used for comparative analyzes and in the calculation of the Clarks of the elements in the phytomass.

20. Participation in the pilot phase of the first monitoring studies on ozone pollution of the surface air in the Sofia region, which were provided to the municipal administration.

Summary: Active biomonitoring was carried out with the bioindicator Nicotiana tabacum L. Cv. Bel – W3 in 33 points in the Sofia region; the index of leaf damage was calculated and a map was made of the areas with visible observed damages; Active biomonitoring was carried out using two-year plants *Quercus robur* L. (sensitive to ozone pollution) and *Quercus rubra* Michx. (sustainable) for one growing season in 2 points - control and with available pollution; ozone concentrations, humidity and surface air temperature were monitored for the study period; the number of leaves, leaf area, intensity of transpiration and damage to the leaf phytomass in both points were recorded; differences in the effect between two species and experimental points were found; Passive biomonitoring was conducted at 8 points with 16 coniferous and broad-leaved trees and 3 shrub species. Visible damage to broad-leaved and conifer species was assessed according to a point system recommended by ICP-Forest. The points with the first degree of disability have been determined. The research is by a national project and has been published in an international and Bulgarian journals and a collection of international forums.

21. An original model for ecotoxicological testing in agroecology of the plant-soil-water complex when using wastewater for irrigation purposes has been published.

Summary: Ecotoxicological testing of wastewater was done, where the pollutant concentrations were within the recommended norms, but a toxic effect was found on the *D. magna* St. and *P. parva* Temminck & Schlegels., which is probably due to a combinatorial effect of the pollutants; bioaccumulation of Fe and Zn in fish gills was also found. Ecotoxicological testing of wastewater was conducted with a large set of biotests - *Lepidium sativum* L., *Raphanus sativus* var. *radicula*, *Medicago sativa* L. (variety Pleven), *Zea mays* L. (variety Kneja 509- hybrid, 3-th fraction) and *Triticum vulgare* Host. (variety Sadovo), which are cultivated in the area, taking into account the parameters: energy of germination and germination of seeds, length and weight of root and stem of sprots and bioaccumulation of Fe and Zn in the plant biomass. The biotests were treated with soil extracts. Soil respiration was also measured. The established effect of biostimulation and the bioaccumulation potential of cultivated plants to the investigated heavy metals in wastewater generate a significant risk for the agro-ecosystems and the

population in the region. A number of studies have also been conducted on the toxic effect of treated industrial waters, before their discharge into the Iskar River, guppies were used as biotests.

22. The main theoretical statements in the field of ecotoxicology are summarized in a book chapter.

IV. CONTRIBUTIONS FROM ECOSYSTEM SERVICES PUBLICATIONS (B5-6; C15; D23-32, D34, D36; E13-14, E41, E49, E50, E54, E57, E60, E63, E67, E73; F35-37, F53; G1 – 19; G2 – 14, 20, 22, 23) – 9 applied contributions.

Several publications have developed new aspects of ecosystem services that plants can provide. Co-authored studies on *Chenopodium botrys* L. and *Rosemarinus officinalis* Lin. as a source of biologically active substances - a phytoecological characterization was made, the chemical composition of the essential oils was investigated, and the bactericidal, fungicidal and herbicidal effects of the oils and the water extract from the phytomass were tested. Summary information is reported based on researched literature sources on the capabilities of genus *Spirulina* Turpin and *Amaranthus* L. as an effective source of proteins and biologically active substances, also the services provided by protected territories and zones in the Osogovo mountain as an opportunity for the development of local communities.

Attention is paid to ecological management of ecosystems (DPSIR) and forest ecosystems using information technologies. Information on ecosystem services and forest ecosystem services is summarized, some ecosystem services in urbanized areas and the forest ecosystem service for the quantity and quality of water resources are developed. The payment schemes for ecosystem services and their cost effectiveness have been developed, as well as a Web platform for the structural description of payment schemes for ecosystem services.

Commented on the need to connect the two major modern strategies – sustainable development and innovative economy, expressing and ensuring the aspiration to raise the living tandard of human society and the need to preserve the biosphere. Commented on the need for an active and constructive dialogue between the various scientific communities, business, economy and various social circles. The relationship between the "Future of internet", ecosystem services and sustainable regional development is examined.

23. The original information was published on the chemical composition of the essential oil, also its bactericidal, fungicidal and herbicidal effects, as well as that of the water extract from the phytomass of *Chenopodium botrys* L. and *Rosemarinus officinalis* Lin. that can be used in pharmacy, medicine and agronomy.

The research was done as part of a university project and was published in international journals.

24. The first scientific book in Bulgaria was published, containing summarized information on ecosystem services and benefits, as well as publications developing the topic.

25. The first book in Bulgaria was published, containing general information about forest ecosystem services, payment schemes and their cost effectiveness, as well as publications developing the topic.

26. Forest ecosystem services for the quantity and quality of water and the cost effectiveness of payments have been developed jointly under the COST program.

The materials have been published in a manual, a book chapter and 2 international journals.

27. Publications on the Use of Developed Technologies (DPSIR) for Ecosystem Management as well as Information Technology for Ecological Forest Management. – 2 publications in international journal and conference proceeding.

28. Valuation of the ecosystem service 'pollination' in urbanized ecosystems - the paper has been published as a book chapter.

29. Ideas are published about the need for global integration of modern strategies formed by different scientific communities and their transformation into a mega-strategy, which were relevant for global policies and the sustainable existence of the biosphere and humanity – publications in 2 international journals.

30. Publication of ideas on connection between the global strategies "Future of internet", "Ecosystem services" and "Sustainable regional development" - publication in a collection of an international forum.

31. A web-platform has been created for the structural description of payment schemes for ecosystem services - publication in an international proceeding.

V. EDUCATIONAL – METHODICAL AND POPULAR CONTRIBUTIONS (C7 – C15, F40 –F53) – 8 contributions.

1. The first book in Bulgaria on "Dendrochronology" was published. The book includes theoretical statements, main directions and work instructions.

2. The first book of its kind in Bulgaria "Phytoecology" (2004) was published, in which all aspects of plant ecology are considered, also included: a practical course; self-study tests and data from the author's research.

The book "Phytoecology" includes the author's full course "Phytoecology", part of the lecture courses - "Bioresources and their conservation", "Methods of ecological research", "Ecological monitoring", "Ecology and environmental protection". The book can be used by students, teachers and a wide range of specialists interested in plant ecology.

3. The first book of its kind in Bulgaria on "Functional Biocenology" was published (2005, 2009), which includes some summaries and illustrations from the author's research and self-training tests.

Commented on: the main functional features of macrobiological systems, the possibilities for their use in assessing the condition; the main factors resulting in their change in the anthroposphere and modern strategies for maintaining the balance in the Biosphere. The book includes the author's full course "Functional biocenology", part of the lecture course "Methods of ecological studies", "Ecology and environmental protection" and "Ecotoxicology". The book "Functional Biocenology" can be used for the education of students, doctoral students, specializants and a wide range of specialists.

4. The first methodological aid of its kind for Bulgaria was published - "Guide to functional biocenology", in which methods and indicators for functional studies and evaluation scales are summarized and adapted by the author. A set of practical tasks has been developed, including original data from the author's research.

The book can be used for the education of bachelors and masters, for students and doctoral students interested in ecology and environmental protection and ecotoxicology. It can be useful to a wide range of specialists in related fields.

5. The first of its kind methodical book - 'Ecotoxicology - a small practical guide' (2007, 2009) has been published, which presents basic theoretical principles, methods, and indicators, as well as various types of biotests, which are examined according to two main classifications.

The book "Ecotoxicology - a small practicum" includes laboratory classes in the discipline of Ecotoxicology, included in the curriculum for bachelors in Biomanagement, masters in "Environmental Protection" and masters in "Ecochemistry" in the Faculty of Biology and Chemistry of Sofia University "St. Kliment Ohridski". It can be useful for all specialists dealing with environmental protection in a scientific or practical aspect - from the specialized ecotoxicological laboratories in the Center for Public Health Protection, in the Executive Agency for the Environment, from the Ministry of Education and Culture and its regional structures (RIOSV), from the Basin Directorates, from the Ministry of Health and its regional structures, from the NUG and its regional structures (RUG, etc.), as well as from other structures and institutions conducting ecotoxicological control and monitoring studies.

6. The first book of its kind in Bulgaria - "Chronoecology" was published.

Biological rhythmicity is considered as a synthesized adaptation with an exo-endogenous nature in different biological systems and its change - an expression of ecological plasticity and a basis for the evolution of systems. The influence of anthropogenic factors on the natural chronology of biological phenomena at different levels is considered. Practical classes include analyzes in the field of dendrochronology and dendroecology.

The book "Chronoecology" covers the elective lecture course of the same name for masters from specialty "Ecology and environmental protection" at the Faculty of Biology of the SU "Kl. Ohridski". It can be useful to students and specialists studying the various fields of natural sciences.

7. The book "Ecosystem Services and Benefits - Costs, Effectiveness, Payments" has published.

The book summarizes information about ecosystem services and benefits, types, how payment schemes are developed and their cost effectiveness. It can be used by a wide range of professionals as well as for university teaching purposes.

8. A series of publications are dedicated to popularizing contemporary ecological directions and methods among the general public and teachers in secondary schools.

In these publications, the following are commented: the mechanisms of self-management and maintaining the stability of macrobiological systems; the essence of the ecosystem approach for their modeling; the main approaches for ecosystem diagnostics; nature and application of the dendrochronological method; nature and importance of ecotoxicology as a science; biotests in ecotoxicology and ecotoxic effects of tropospheric ozone, etc.

Prof. Dr. Mariyana Lyubenova