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ENGINEERING LANDSCAPE SCIENCE IN UKRAINE CURRENT STATE AND FOREIGN EXPERIENCE

The problem of revival of the scientific direction – engineering landscape science is considered. The theoretical-methodological basis is the studies of Prof. F. M. Milkov and Prof. G. I. Denysyk about anthropogenic landscapes. A landscape techno-sphere – a landscape technical system of a global level – was suggested as the object of the research. It is a specific combination of the components of a landscape sphere and a techno-sphere within geographical boundaries. The subject of the research is: structure, outer and inner interconnections, the functioning dynamics of a landscape techno-sphere as an integral system. The place of engineering landscape science in the structure of landscape sciences was considered. The formation process of engineering landscape science in Ukraine and its connection with foreign scientific trends were analyzed. The conclusion has been made that presently engineering landscape science continue to remain at the initial stages of the development. The task of engineering landscape science for the future was outlined.

Keywords: anthropogenic landscapes, landscape-technical systems, geotechnical systems, natural-technical systems, engineering landscape science, engineering ecology, technoecology.

Лаврик О. Д., Цимбалюк В. В., Стефанков Л. І. ІНЖЕНЕРНЕ ЛАНДШАФТОЗНАВСТВО В УКРАЇНІ: СУЧАСНИЙ СТАН І ЗАРУБІЖНИЙ ДОСВІД

На початку XXI ст. антропогенне ландшафтознавство досягло значних успіхів у дослідженні техногенного впливу на ландшафтну сферу. Однак, для того, щоб здійснювати детальний аналіз усієї різноманітності антропогенних ландшафтів замало умінь лише фізико-географів і ландшафтознавців. До цієї проблеми необхідно залучати фахівців інженерних спеціальностей. Шляхом синтезу знань про структуру та закономірності розвитку ландшафтів і практичних навичок техногенної трансформації природи вчення про антропогенні ландшафти може суттєво доповнити інженерне ландшафтознавство. Метою дослідження є визначення та наукове обґрунтування теоретичних і практичних аспектів, та перспектив сучасного розвитку інженерного ландшафтознавства. Основою цього дослідження є матеріали багаторічних польових спостережень, проведених у контексті вчення про антропогенні ландшафти проф. Ф.М. Мількова та Вінницької школи антропогенного ландшафтознавства проф. Г.І. Денисика. Формування

наукового апарату ґрунтується на загальнонауковій модельній парадигмі, концепції геотехнічних систем та принципах генетизму, історизму та природно-антропогенного сумісництва. У процесі розробки теоретико-методологічних основ інженерного ландшафтознавства поєднано методи дедукції, індукції, моделювання, екстраполяції, класифікації, історико-географічний, ландшафтних аналогів тощо.

Розглянуто проблему відродження наукового напряму – інженерного ландшафтознавства. Зазначено, що зараз інженерне ландшафтознавство не має чітко визначеного понятійно-термінологічного апарату та досконалої методики польових досліджень. Зроблено порівняння об'єктів дослідження інженерного ландшафтознавства та інших інженерних наукових напрямів. Основою сучасної теоретико-методологічної бази інженерного ландшафтознавства є вчення проф. Ф.М. Мількова та проф. Г.І. Денисика про антропогенні ландшафти. Як об'єкт досліджень запропоновано ландшафтну техносферу – ландшафтно-технічну систему глобального рівня як специфічного поєднання складових ландшафтної сфери і техносфери у межах географічної оболонки. Предмет досліджень: структура, зовнішні і внутрішні взаємозв'язки, динаміка функціонування ландшафтної техносфери як цілісної системи. Зазначено, що інженерне ландшафтознавство залишається складовою дисциплін природничого циклу і у той же час є частиною комплексу інженерних й суспільних наук. У системі ландшафтознавчих наук інженерне ландшафтознавство знаходиться на нижчому таксономічному рівні від техногенного ландшафтознавства і вже зараз почало диференціюватися на окремі наукові напрями. Виокремлення нових класів антропогенних ландшафтів, регіональні дослідження ландшафтно-технічних систем (ЛТС), ідентифікація об'єктів індустріальної спадщини як причини трансформації сучасних ландшафтів дають можливість стверджувати, що інженерне ландшафтознавство буде розвиватися у подальшому як самостійна наука. Початком розвитку інженерного ландшафтознавства стали ідеї та розробки провідних географів колишнього СРСР у XX ст. (Ю.П. Пармузіна, Л.Ф. Куніцина, В.С. Преображенського, Ф.М. Мількова, А.Г. Ісаченка). Важлива роль у становленні наукового напряму належить дослідженням представників Вінницької школи антропогенного ландшафтознавства. У зарубіжній науковій літературі спорідненими напрямами до інженерного ландшафтознавства є низка прикладних дисциплін, серед яких геотехнічна інженерія, інженерна екологія, екосистемне управління, індустріальна екологія, ландшафтна інженерія тощо. Зроблено висновок про те, що зараз інженерне ландшафтознавство продовжує залишатися на початкових етапах розвитку. Визначено завдання інженерного ландшафтознавства на перспективу, серед яких: формування єдиного понятійно-термінологічного апарату для інженерів та географів; розробка універсальної методики польових досліджень ЛТчС; аналіз розвитку ландшафтно-технічних систем в історико-географічному аспекті; вивчення прикладних аспектів взаємодії трьох блоків ландшафтно-технічної системи; ідентифікація стадій розвитку ландшафтно-технічних систем; дослідження вертикальної і горизонтальної диференціації ландшафтно-технічних систем; аналіз проявів азонально-зональних особливостей ландшафтно-технічних систем; вивчення особливостей симетрії та асиметрії ЛТчС; виявлення специфіки геофізичних і геохімічних аспектів (динаміки) функціонування ЛТчС різного господарського призначення; дослідження ЛТчС у межах геоекотонів різного рангу; розробка єдиної схеми оптимізації раціонального використання ландшафтно-технічних систем тощо. Синтезуючи попередні досягнення у галузях інженерних, природничих і суспільних дисциплін, інженерне ландшафтознавство буде логічним продовженням розвитку вчення про антропогенні ландшафти. Інженерно-ландшафтознавчі дослідження дадуть змогу здійснювати ефективну підтримку ландшафтно-технічних систем в оптимальному стані та забезпечити їх довготривале функціонування.

Ключові слова: антропогенні ландшафти, ландшафтно-технічні системи, геотехнічні системи, природно-технічні системи, інженерне ландшафтознавство, інженерна екологія, техноекологія.

Relevance of the research theme. At the beginning of XXI century anthropogenic landscape science made a big progress in studying a techno-genic effect on a landscape sphere. However, in view of the mentioned topic, this science itself cannot reach the goal. The skills of physicists-geographers and landscape experts are not enough to make a detailed analysis of the whole variety of anthropogenic landscapes. It is advisable to get the specialists of engineering occupations involved in this process. Through the synthesis of the knowledge about the structure and regularities of the landscape development and practical skills of a techno-genic transformation of nature, the studies of Prof. F. M. Milkov and Prof. G. I. Denysyk about anthropogenic landscapes can be a substantial supplement to engineering landscape science – *a scientific trend directed towards the research of landscape-technical systems (LTchS) as the components of a landscape techno-sphere, their structure, development, functioning, outer and inner dynamics, which is to be carried out at landscape, geographical and geotechnical levels of knowledge.*

State of studying the issue, the main works. Scientists began detailed research into the interaction of nature and technology, as well as the mechanisms of their management in the 60ties. Famous geo-physicist G. F. Hilmi stated a important role of technical means in the active transformation of environmental and he came to a conclusion that "starting with the transformation of nature, man will definitely turn to its organization and eventually he will have to create an absolutely new biosphere which will consist of a physical environment and organisms that will inhabit it, and technical devices which will control and form this physical environment" [1, p. 284].

The beginning of the development of engineering landscape science was the article of Yu. P. Parmusin [2], where he, based on his long-term research of nature in Siberia, grounded the expediency of a detailed studying of the interaction of engineering constructions with landscapes, the structure of which they changed.

The Department of physical geography of the Institute of geography of the Academy of sciences of the USSR, headed by L. F. Kunitsyn and V. S. Preobrazhenskyi, worked on this problem from the mid of the 60ties of XX century. The concept "a geotechnical system" was substantiated in their works [3], later it became the object of studying in ameliorative geography – the science about the ways and kinds of the transformation of natural environment (geosystem) for the optimization of its properties aimed at increasing biological (agricultural) productivity [4]. F. M. Milkov [5] differentiated the terms "a landscape-engineering system" and "a landscape-techno-genic system" and considered engineering landscape science to be a promising trend in physical geography. A. G. Isachenko [6] and V. S. Preobrazhenskyi [7] classified applied landscape science as a constructive trend in researching natural complexes which were changed due to man's technical activity.

Foreign scientists carry out the researches in the sphere of *landscape engineering* which are close to engineering landscape science by its contents. L. G. Carpenter, a leading expert in the irrigation systems who studied irrigation systems in North America and Europe, is the founder of this trend. At the end of XIX century he worked out the first educational program in the USA aimed at training experts in the sphere of hydro-technical construction. Presently landscape engineering deals with solving a wider range of problems associated with the development of landscape architecture. So, G. T. McKenna considers "landscape engineering" to be an interdisciplinary branch which envisages the use of technology and applied sciences in the designing and creation of anthropogenic landscapes [8]. M. Cetin carries

out such researches which are aimed to protect build-up areas (residential landscape, O. L.) from emergencies of different nature [9]. D. R. Steward and E. A. Bernard combine the technique of engineering and landscape planning to solve the problem of lowering of soil water levels [10]. F. Celik believes that current ecological problems result from certain miscalculations in landscape planning, and he outlines such new scientific trend as ecological landscape design [11]. According to [12], landscape engineering is of great significance in economic sense – to determine financial expenses for the use of water resources, labor and support of the optimal condition of the designed landscape. Beginning from 2005, the International consortium in landscape and ecological engineering for the protection and improvement of the environment in the conditions of the decrease of bio-diversity, desertification, global warming and other ecological conditions initiated the edition of journal "Landscape and Ecological Engineering" [13]; there original papers, reports and reviews in all aspects of conservation, restoration and management of ecosystems are presented.

In the second half of XX century, despite a growing interest of the scientists to the system of the interaction between nature and technology, engineering landscape science failed to become separate science. Landscape-technical systems [5; 14], (geotechnical systems [15], natural-technical systems [16]) were considered in the context of the research of various scientific trends. Nowadays more than ten sciences (geoecology, landscape ecology, system technoecology, etc.) exist and they interpret these definitions in different variations. This situation creates a certain inconsistency in the opinions among the representatives of engineering and natural sciences concerning the object under study. Engineering landscape science – "a carelessly forgotten" scientific trend – can solve this problem provided its scientific principles undergo detailed development.

Purpose of the research is: to determine and scientifically substantiate theoretical and practical aspects, prospects of modern development of engineering landscape science.

Methodology of the research: the grounds to publish this research are the materials paper were the materials of long-term field observations, carried out in the context of the studies about anthropogenic landscapes, of Prof. F. M. Milkov [5] and of Vinnytsia school of anthropogenic landscape science of Prof. G. I. Denysyk [14]. The formation of scientific apparatus is based on a general scientific model paradigm, a concept of geotechnical systems [3] and the principles of genetism, historism and natural-anthropogenic compatibility. The methods of deduction, induction, modeling, extrapolation, classification, historical and geographical, landscape analogs, etc., were combined in the process of the development of theoretical-methodological principles of engineering landscape science.

Presentation of the main material with the explanation of the received scientific results. The central place in engineering landscape researches is occupied by "a landscape-technical system" (LTchS) – *this is a block system where a technical block is combined with a natural one within a concrete landscape to perform certain social tasks which determines a drastic transformation of all or at least one of geo-components of a natural block and changes the processes of the exchange with a substance, energy and information inside the system and with adjacent landscapes.*

Although half a century has passed since the first reference about LTchS, yet this scientific trend has no unified conceptual and terminological apparatus and a complete methodology of field trials. From the first sight, a concept "engineering landscape science" is only a synonymy of such engineering scientific trends as "engineering geography", "engineering geomorpholo-

gy", "engineering ecology", etc. In fact it is not so at all. Engineering landscape science are directed towards a comprehensive studying of landscape-technical systems, whereas other scientific trends study individual geo-components or blocks of LTchS (Fig. 1).

Usually, when studying landscape-technical systems by other engineering scientific directions, the differentiation of the object of research into basic and indirect is clearly observed. So, engineering geography focuses on a natural block of the system, engineering geology – on upper horizons of an earth's crust (rocks and soils), engineering hydrology focuses on water mass, etc. Alongside with this, indirect objects of the research are technical (an engineering structure) and managerial (an operator) blocks of the system. Environmental engineers (techno-ecologists) study the interaction of techno-genic cover and all geocomponents and indirectly take into account the control block. A prior role in the research is given to the interaction "man – engineering structure" for ergonomics (human factors and ergonomics), and the result of these interactions (a natural block) remains out of researchers' focus. Instead, engineers-landscape experts have to equally analyze the behavior and response of each of the three blocks.

Besides, as other scientific trends are aimed at controlling the system from the moment of projecting to the termination of the functioning of the main engineering structure, engineering landscape science LTchS even after the stage of the total damage. An innovation aspect predetermines this. The destruction of the system does not imply its total "collapse". Based on such anthropogenic landscape, it is possible to create an open-air museum, to form recreation parks environmental zones, to restore rare species of plants and animals. And the knowledge about the origin of an anthropogenic landscape; the specific aspects of the function of an engineering structure; the processes and events which took place in the former LTchS, are of great importance.

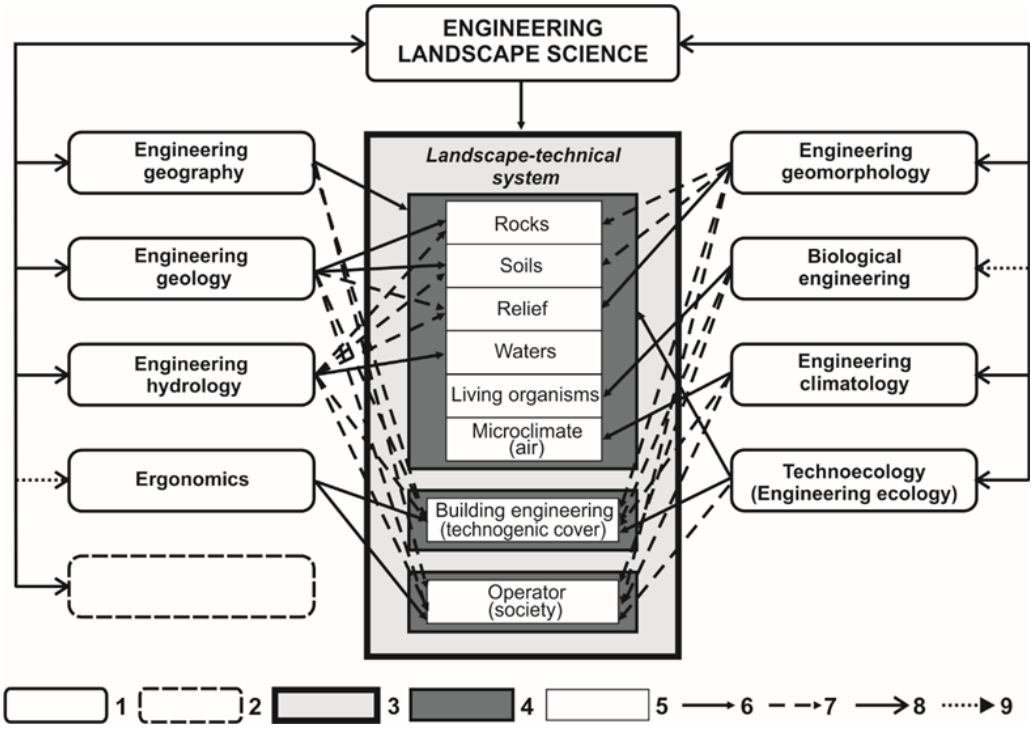
The object of the research of engineering landscape science is a landscape techno-sphere – a landscape-technical system of a global level. It is a specific combination of the components of a landscape sphere and a techno-sphere within geographic boundaries. At present a landscape techno-sphere has no entire spread, but gradually it increases in sizes and can go beyond a landscape sphere. In case of technicality enhancement, a landscape techno-sphere can transform other spheres of a planet and replace them with itself.

The subject of the research of engineering landscape science is a structure, outer and inner interconnections, the functioning dynamics of a landscape techno-sphere as an integrated system.

Thus, engineering landscape science remains to be both part of the subjects of a natural cycle and part of a complex of engineering and social sciences. This makes it possible to use their theoretical-methodological basis for an equivalent estimation of a three-block structure and the functioning dynamics of landscape-technical systems.

In Ukraine applied physical geography became the basis for the development of engineering landscape science – a scientific trend, generalized by P.G. Shyshchenko based on long-term observations of the interaction between nature and engineering. He suggested the object of applied physical-geographical research, namely – "a territory, a natural-territorial complex, a physical-geographical process or their combination, regional physical-geographical taxa of different ranges which are studied and estimated from a practical point of view" [17, p. 8].

Later, a serious contribution to the formation of engineering landscape science was made by the fundamental works of the scientists at the Universities of: Vinnytsia – (G.I. Denysyk); Dnipro – (O.O. Kernychna); Kyiv – (V.V. Stet-



Scientific trends: 1 – available; 2 – potential. **Limits:** 3 – systems; 4 – blocks; 5 – components. **Pointers to the objects under study:** 6 – basic; 7 – indirect. **Ties between scientific trends:** 8 – adjacent; 9 – separate.

Fig. 1. Research objects of engineering scientific trends in the framework of a landscape-technical system

siuk, O.Yu. Dmytruk, M.D. Hrodzynskyi, Yu.A. Siletskyi); Kharkiv – (V.Yu. Nekos); Kryvyi Rig – (Yu.H. Tiutiunnyk, L.M. Bulava, V.L. Kazakov); Lviv – (K.I. Herenchuk, M.M. Koinov, I.S. Kruhlov, I.P. Kovalchuk, V.M. Petlin, H.I. Rudko, Ye.A. Ivanov); Melitopol – (V.P. Vorovka); Ivano-Frankivsk – (O.M. Adamenko); Odesa – (H.I. Shvebs]); Simferopol – (Yu. I. Hlushchenko, K.A. Pozacheniuk); Chernivtsi – (Ya.R. Dorfman, L.I. Voropai, V. M. Gutsuliak, M.V. Dutchak), etc.

From the 70ties of XX century a group of the representatives of Vinnytsia school of anthropogenic landscape science, headed by professor G.I. Denysyk [14], carry out the research of anthropogenic landscapes of Ukraine. Some publications of O.O. Antoniuk [18], O. I. Babchynska [19], I. P. Gamaliy [20], A.V. Gudzevych [21], V. V. Kanska [22], A. G. Kiziun [23], I. P. Kozynska [24], I.V. Kravtsova [25], G.S. Khaietskyi [26] L.M. Kyryliuk [27], O.M. Valchuk [28], I.M. Voina [29], V.M. Volovyk [30; 31] and Yu.V. Yatsentiuk [32] deal with the studying of landscape-technical systems. Some aspects of the regional spread of LTchS on the example of river valleys of the Right-bank Ukraine were examined by the authors [33–35].

Some interesting ideas and developments belong to geographers from Kryvyi Rih (V. L. Kazakov [36], I. M. Malakhov [37], Yu.G. Tiutiunnyk [38], S.V. Yarkov [39], H.M. Zadorozhnia [40]), who develop a similar trend "technogenic landscape science" on the example of mining landscapes of their region. One of the genetic groups of anthropogenic landscapes – techno-genic – occupies a central place in these researches. With this approach in mind, the mentioned trend is much wider, as a structural organization of techno-genic landscapes[1] includes "landscape-engineering

1 The formation of techno-genic landscapes is associated with various branches of construction. In taxonomic terms, technogenic landscape science is at the highest level in relation to engineering landscape science. Now this area is also at an early stage of development

systems", "landscape-techno-genic systems" and "anthropogenic landscapes themselves" (Fig. 2).

The suggested ideas made it possible to create a trend structure of the system of landscape sciences and to show the place of engineering landscape science in it (Fig. 3). Now it has begun to differentiate into separate scientific areas. The basis for their separation is 8 classes of anthropogenic landscapes. Until recently, such studies were conducted by anthropogenic landscape science. However, the progressive growth of the role of landscape-technical systems in the structure of anthropogenic landscapes proves that the study of these classes is the prerogative of engineering landscape science.

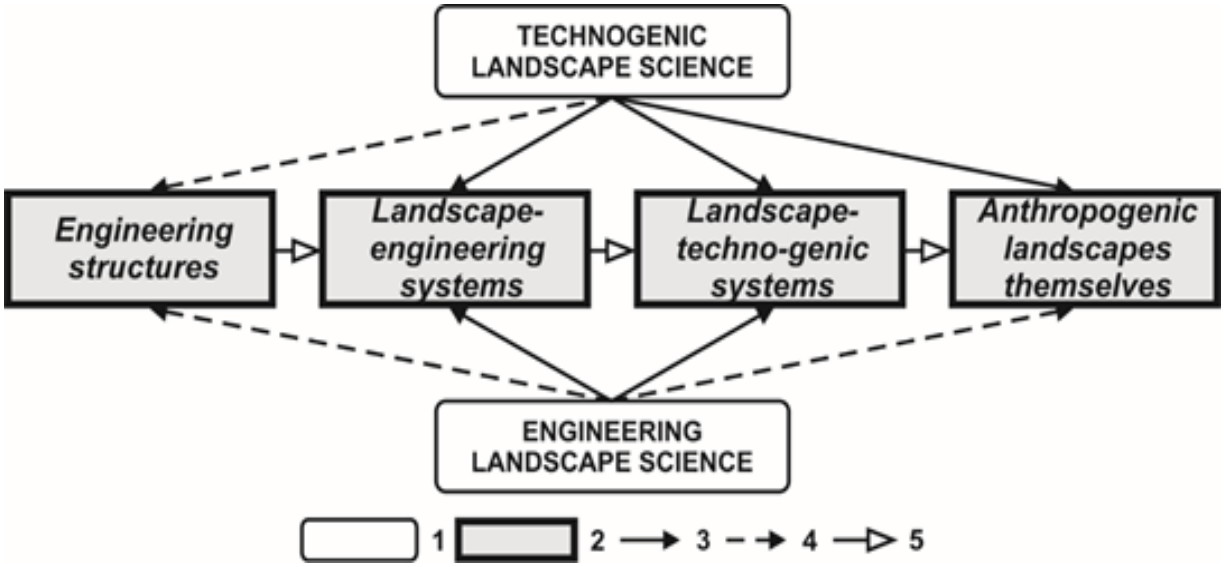
This is not a final scheme. The appearance of new classes of anthropogenic landscapes (sacred and taffal) [37]), the regional research of landscape-technical systems [32; 35; 36], study of mass and energy exchange processes in regional paradynamic anthropogenic landscape systems [41], the identification of the objects of industrial heritage as the reason for transformation of modern landscapes [42] give every ground to state that engineering landscape science will further develop as an independent science. In parallel with it, other landscape areas will be formed, the selection of which will depend on the current needs of society and the peculiarities of the development of the landscape sphere. An important role in their formation belongs to historical and natural landscape studies, which are aimed at studying the spatio-temporal transformation and preservation of paleolandscapes. Engineering and landscape research will help determine the optimal ratio of natural landscapes and landscape-technical systems in the structure of modern landscapes.

In foreign scientific literature a set of applied subjects are related to engineering landscape science which develop on the basis of *geotechnical engineering*. Nowadays this is a branch of civil construction which deals with the studying of mechanical, hydraulic and engineering properties of the materials of geological environment used for construction work. As science, it is based on the principles of soil mechanics and rock mechanics founded by Austrian-American geologist K. Terzaghi in 1925 [43]. His followers (R. B. Pek, G. Mesri [44]; R. D. Hholtz, W. D. Kovacs [45]; B. M. Das [46] and others) used the main ideas of geotechnical engineering in practice.

Engineers-geo-technicians deal with the designing of the foundations of engineering structures taking into consideration only some geo-components of a landscape (rocks, soils, topography, underground waters). In their understanding a geo-technical system is an engineering structure which has a direct connection (in the form of the foundation) with the earth surface. Most of the foreign publications in this direction are concentrated on the studying of the reliability and stability of geo-technical systems [47] and the risk evaluation of accidents and emergency situations of different nature [48].

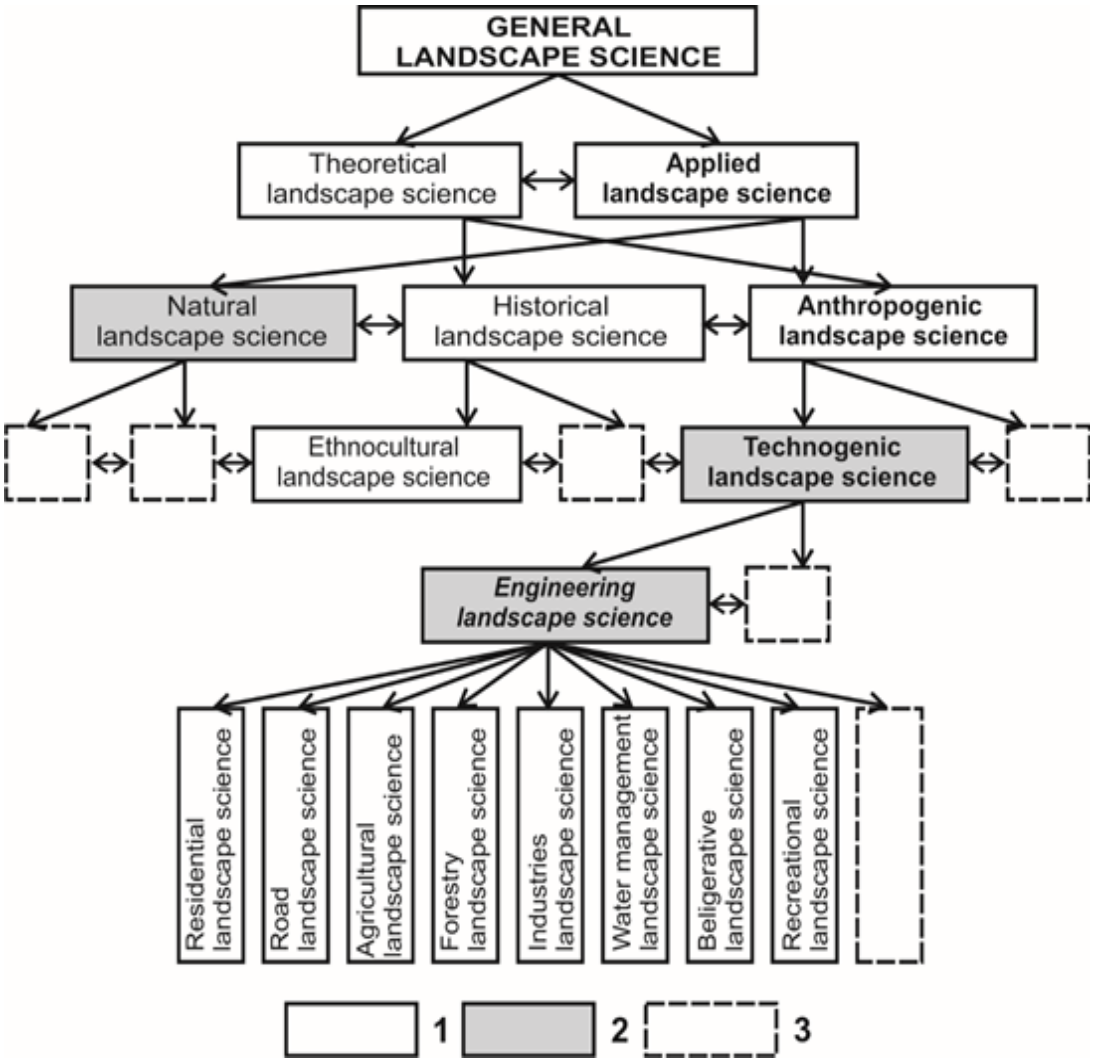
Due to the intensification of the global ecological crisis, leading world universities teach engineers-ecologists for various branches of the industry. Their major curriculum is *environmental engineering* – a direction of applied science and technology which deals with the problem solution of the conservation of energy, production asset and the control over the wastes of vital activity. *Ecological engineering* is an important component in the training of such specialists which is directed towards the creation of stable ecosystems, the integration of human society and the environment. The main task of engineers-ecologists is to control the functioning of engineering-technical structures which break the condition of adjacent ecosystems. The majority of the employees in the Environmental Protection Agency of the USA (EPA) are specialists in

and requires detailed development of theoretical and methodological framework.



1 – scientific trends; 2 – systems as objects of research; 3 – a pointer to basic object of research; 4 – a pointer to indirect object of research; 5 – direction of system modification.

Fig. 2. Objects of research of technogenic landscape science and engineering landscape science



1 – available scientific trends; 2 – promising research trends;

3 – scientific trends at the initial stages of development.

Fig. 3. Place of engineering landscape science in the system of landscape sciences

engineering ecology.

In the 60ties the idea of ecological designing, one of the ways to use natural power sources, was suggested by H. T. Odum as the main approach to the management of ecological systems [49]. W. J. Mitsch and S. E. Jorgensen were the first to ground the principles of ecological designing; they believe that its main purpose is to restore ecosystems, destroyed by the economic activity, and to develop new stable ecosystems which are of great importance both for people and environment [50]. K. R. Barrett characterized the role of ecological designing in the use of water resources. The ecologist states that this scientific trend is "an economically effective strategy to solve the problem of "the second generation" of water resources. It can be defined as designing, construction, operation and management of landscape/water structures, and also plant and animal groupings, connected with them, to improve the state of the environment" [51, p. 182].

Foreign scientists consider *ecosystem management* to be one of the main approaches to the restoration of the condition of the environment. It consists in the management of ecological systems along with the preservation of their main functions, the restoration of natural resources and the satisfaction of social-economic, political and cultural needs of current generations and generations to come [52]. A manager estimates the balance between the scope of a certain kind of natural resources and the needs of society. If the ecosystem provides the restoration of these resources, then an optimal possible output is determined so that a geo-component could replenish its amount [53]. To monitor the state of natural resources, geo-information systems and methods of distant sounding of the Earth are actively applied. Current scientific researches as to the optimization and management of the condition of the environment are based on spatial modeling of the conduct of transformed ecosystems [54]. To preserve natural resources on a landscape level, managers use the formation of ecological corridors for the connection between broken ecosystems or focus on the preservation of a key biological species which is the most sensitive one during landscape transformation [55]. However, in a landscape sense, such methods are not always efficient and they require a complex approach to the estimation of the role of all geo-components in the system.

Joint researches of R. A. Frosch and N. E. Gallopoulos [*56*] initiated the start of the development of *industrial ecology* – an applied scientific subject which studies the interaction of industrial production with the environment and ensures the creation and rational functioning of natural-industrial systems. The functioning of such systems should be based on the laws of nature according to which the wastes of one biological species can be the resource for the other. In January, 2000 the International society of industrial ecology (ISIE) was founded at the session of New York Academy of sciences. Presently the principles of industrial ecology are used in the economy of a closed cycle which is followed by the most developed countries of the planet.

Conclusions and research challenges. Engineering landscape science is still at the initial stages of its development. Its place in the system of landscape subjects has not been defined enough. However, it is obvious that engineering landscape science can differentiate into various scientific trends depending on the economic specificity of a techno-genic block of LTchS. Synthesizing previous achievements in the spheres of engineering, natural and social subjects, engineering landscape science will be a logical continuation of the development of the theory about anthropogenic landscapes. Engineering and landscape research will allow

for effective support of landscape and technical systems in optimal condition and ensure their long-term operation.

In view of this, the promising tasks of engineering landscape science should be the following: the formation of a unified conceptual and terminological apparatus for engineers and geographers; the development of universal methodology of field research of LTchS; the analysis of the development of landscape-technical systems in a historical-geographical aspect; the studying of applied aspects of the interaction of three blocks of a landscape-technical system; the identification of the development stages of landscape-technical systems; the research of vertical and horizontal differentiation of landscape-technical systems; the analysis of the manifestation of azonal-zonal peculiarities of landscape-technical systems; the studying of the peculiarities of symmetry and asymmetry of LTchS; the identification of the specificity of geophysical and geochemical aspects (dynamics) of the functioning of LTchS with different economic purpose; the research of LTchS within geo-ecotones of a different range; the development of a single scheme of the optimization of a rational use of landscape-technical systems, etc.

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