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Modern technologies in forest protection – an attempt to use an electronic nose for detecting harmful insects and pathogens

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Since January 2018, a scientific consortium composed of the Faculty of Physics, Warsaw University of Technology (project leader); Department of Forest Protection, Forest Research Institute (co-executor); and RS CORAS enterprise (co-executor – implementing unit) has implemented a project with the acronym PROZEL 'Forecasting threats to forest ecosystems through the implementation of innovative electronic odor recognition system'. The project received funding for the period 2018–2020 in the third edition of the BIOSTRATEG program 'Environment, agriculture and forestry'.

An extremely dynamic development of modern technologies and knowledge about the mechanisms determining odour in biological olfactory systems observed in the past decades resulted, amongst others, in the development of tools for monitoring and identifying of fragrances, including electronic noses. Those devices, commonly known as e-noses, can detect and recognise odours in the range beyond the capabilities of the human sense of smell, thanks to the gas or chemical sensors inside. Olfactory sensation received by humans and animals are an effect of the influence of those stimuli on receptors located in the olfactory epithelium, which are capable of identifying even several hundred chemical volatile compounds. In the e-nose, the epithelium functions are fulfilled by sensors' matrices that are selectively sensitive to particular fragrance components. Their stimulation leads to generation of specific signals that, along with the algorithm-based data processing system and the recognition of odour patterns, allow to a selective recognition of odours.

How dynamic is the development of this type of devices is evidenced by the increase in the number of publications on e-noses within the past 10 years, from several dozen to nearly 700 items in 2017, according to PubMed database. Electronic noses are increasingly used in many areas of life. They are used to assess odour nuisance in monitoring environmental pollution in the zones affected by sewage treatment plants or landfills, in the perfumery industry to assess the authenticity of products of well-known companies and in the military industry, amongst others, to identify combat gases or to detect dangerous substances, for example, at the

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airports. Electronic noses are also widely used in the food industry in assessing the degree of freshness and quality of food, including the determination of the coffee aroma, beverages and fragranced food additives. In addition, some research on the use of e-noses for the detection of certain diseases, such as tuberculosis, cancer or diabetes based on odours emitted by cancer cells, bacteria or diseased tissues, which allows the detection of the disease at an early stage, is underway.

The use of e-noses provides many opportunities to detect various types of odours in the environment, including forests ecosystems endangered by massive occurrence of insects or pathogens (fungi and oomycetes) attacking forest trees. Contemporary forest protection is based on the integration of various methods leading to the reduction of the threat and extent of damage caused by insects and pathogenic organisms and the selection of the optimal protective method that uses a multi-stage Decision Support System. In turn, the decision-making process is influenced by a complex of actions, which in the case of leaf-eating insects includes, in the first stage, identification of a pest based on the species of insect on autumn searches of the original pine pest, tree clipping on the canvas, insect monitoring using pheromone traps and so on. PROZEL project aims to build an e-nose based on sensors with high sensitivity and adapt it to measure the degree of threat to the forest through pine-tree lappet moth (*Dendrolimus pini*), a dangerous pest of pine stands and pathogenic for forest trees; Oomycetes of the genus *Phytophthora* and *Pythium*; as well as fungi causing damping off (species from the genera *Fusarium* sp., *Rhizoctonia* sp. and *Cylindrocarpon* sp.).

As mentioned earlier, the project is implemented by the consortium of three entities, the leader of which leader is the Faculty of Physics of the Warsaw University of Technology. The university has extensive experience in the construction of e-noses that are used, amongst others, to determine the differences between tobacco in different brands of cigarettes, to distinguish arabica and robusta coffee, to recognise fuels with various biocomponents, to detect explosives or to recognise many types of milk. The Department of Forest Protection of the Forest Research Institute since its inception in 1934 has been conducting multidisciplinary research in the field of forest entomology and phytopathology in accordance with the practical needs. The third partner of the consortium, 23 RS CORAS sp. z o.o., conducts activities in the area of implementation of scientific research and development works, both on its own and acquired from other entities. Amongst others, in cooperation with the Warsaw University of Technology, they made a prototype of a portable e-nose aimed at recognising selected pheromones and pathogenic bacteria.

The scope of works carried out has been divided into 13 tasks (WP, work packages) interrelated in terms of content time and performed by individual entities or in cooperation with other consortium members. The research carried out mainly by the institute consists of two modules, of which the first module, phytopathological, includes the following four tasks:

– Preparation of pure cultures of phytopathogens on a solid media (WP 1);
– The artificial inoculation of oak seedlings with pathogens (WP 2);
– Field trials for the detection of the presence of pathogens causing damping off (WP 3);
– Analysis of the archived results (WP 4).

In the entomology module, the following five tasks were distinguished:

– Collection of pine-tree lappet caterpillars in the stands of pine and their breeding in laboratory (WP 5);
– Differences in the release of pheromones by pine-tree lappet caterpillars at various stages of development (WP 6);
– Detection of pine-tree lappet caterpillars overwintering in leaf litter with the use of electronic nose (WP 7);
– Outdoor attempts to detect the presence of pine-tree lappet caterpillars in the tree crowns with the use of electronic nose (WP 8);
– Elaboration of the results (WP 9).

The main executor for tasks 10–12 is the Warsaw University of Technology, on which the basic goal of the project is based, that is, constructing an e-nose based on artificial intelligence (neural networks) and the latest generation sensor matrix with selectivity and detection adapted to odours secreted by the tested insects and pathogens living in a forest environment, which emit a large number of fragrances (WP 10). Specialists in artificial intelligence algorithms of the Warsaw Univer-

sity of Technology will create a system that will be the core of the final device (WP 11).

It will be taught of basic odour patterns based on the scent samples collected in the field and then delivered to the laboratory, separated by the analysed organisms. In this way, a base of fragrance profiles will be created for all tested samples. Then, in the laboratory conditions, the e-nose calibration will be carried out, which will allow to further field work. During this calibration, it will be possible to replace or add some sensors, as well as change in algorithms.

After calibrating the e-nose for odours secreted by caterpillars and pathogens, field studies will be carried out in the areas of their increased occurrence (WP 12). These tests will be carried out in both autumn and spring, that is, in the moments characteristic for the individual development of these organisms. The obtained results will be compared with the methods of detection of pine-tree lappet moth and pathogens that are performed in the traditional way. During these tests, the final work will be carried out to optimise the device so as to create a product ready for implementation. The scope of works defined as part of task 13 (the main executor is 23 RS CORAS) will include, amongst others, the preparation of implementation documentation, including technical documentation of the product together with patent claims and a list of production needs.

The final result of the project implementation will be the preparation of an innovative solution based on the 'artificial intelligence' and a matrix of selective sensors, which in the future should be widely used in the protection of forest ecosystems. The introduction of this type of device for forestry practice can be a valuable complement to the methods that are used to identify leaf-eating insects and pathogens or an alternative way to help employees of the State Forests to detect a pest or disease.