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PRECISION FORESTRY – DEFINITION AND TECHNOLOGIES

"PRECIZNO ŠUMARSTVO" – DEFINICIJA I PRIPADAJUĆE TEHNOLOGIJE

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ABSTRACT: The principle of "precision forestry" is that it uses modern tools and technology to get as much real information as it is possible to improve decision making process and to ensure current goals of forest management. The best known and most frequently used tools of modern technology are remote sensing, navigation systems and geographic information systems. New trends are decision support systems and tools for tree identification and tools for wood material testing and measurement. There is a large interest of the forestry sector in these technologies because as the primary source of data "precision forestry" provides more accurate (realistic) information then currently used sources. Aim of this article is to clarify and inform the professional, but also the general public with the precision forestry, its definition and its tools.

Key words: forestry, remote sensing technologies, surveying, decision support system, Geographic Information System.

1. INTRODUCTION – Uvod

At present, demands for wood production along with increasing economical and environmental public demands from forests require new access to solution as well as new technologies. Detailed data which is collected, analyzed and stored is used for successful management. Profitable management is the result of right planning, organization and control of all forest operations. These claims are reached by implementation of precision forestry.

Precision forestry is new direction for better forest management. Management principles of precision forestry are based on precision agriculture. Precision agriculture is an information-based, decision making agricultural system designed to improve the agricultural process by precisely managing each step to ensure maximum agricultural production and continued sustainability of the natural resources (Rasher 2001, Martinić et al. 2001). Precision agriculture can be defined as managing crop inputs, such as fertilizer, herbicide, etc. on a site-specific basis to reduce waste, increase profits, and maintain the quality of the environment (Taylor et al 2002). It uses set of tools, which have been successfully introduced around the whole World and now they have been used in precision forestry.

Precision forestry is focused on information and supports economical, environmental and sustainable decision by using high technology sensing and analytical tools. It provides highly repeatable measurements, actions and processes to initiate, cultivate, and harvest trees, as well as to protect enhance riparian zone, wildlife habitat, and other environmental resources. It provides valuable information and linkages among resource managers, the environmental community, manufactures and public policy makers (Dyck 2001).

Precision forestry is defined by group of researcher S.E. Taylor, T.P. McDonald, F.W. Corly (2002), as planning and conducting of site-specific forest management activities and operations to improve wood product quality and utilization, reduce waste, and increase profits and maintain the quality of the environment. According to Ziesak`s (2006) opinion, Precision Forestry uses high technology sensing and analytical tools to support site-specific, economic, environmental, and sustainable decision-making for the forestry sector supporting the forestry value chain from bare land to the customer buying a sheet of paper or board.

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2. SCOPE OF RESEARCH – Problematika istraživanja

The most important parts of precision forestry are new and modern technologies.

Precision technologies are instrumentation, mechanization, and information technologies that measure, record, process analyze, manage, or actuate multi-source data of high spatial or temporal resolution to enable information based management practice or to support scientific discovery (Schmoldt, Thomson 2001).

Precision forestry uses variety of tools and techniques, which can be differently categorised. Ziesak classifies techniques into seven main activity fields:

- Surveying (terrestrial laser scanner, GPS, INS and digital surveying equipment),
- Remote sensing (CIR, Airborn laser scanner),
- Contact-free materials testing and measuring computer tomography (CT), ultrasound, video and laser scanner,
- Monitoring - radio frequency identification (RFID) and electronic nose (aroma) technology,
- Decision-making and harvest planning,
- GIS, DSS and visualisation software,
- Computer hardware.

In this article tools are categorized into 5 categories.

2.1. Surveying technologies – *Tehnologije izmjere*

Currently, photogrammetric measurement methods with support of terrestrial measurements using total stations, electronic tachymeter and fieldmaper are dominating in the forest mapping. However, these methods do not provide information on all the details hidden under crops, where there are various complications caused by considerable segmentation and opacity of terrain; that's why geodetic (terrestrial) methods are used for supporting of photogrammetric measurement methods.

• **Forest mapping technology GNSS –** They are highly accurate satellite based radio navigation systems which provide us three dimensional positioning (elevation of the ground and coordinates x, y) and time information. This system gathers data position single objectives (Khali 2001).

GNSS users have now fully available two satellite systems: NAVSTAR system developed by U.S.A and the Russian GLONASS system. The third satellite system GALILEO is the EU project, which aim is to build a new and an advanced satellite system, which would contribute to maximum efficiency in measurements of GNSS. The successful launch and expansion of the GALILEO system would be more than double the number of GNSS signals, which will be available to users (Tuček et al., 2007). Currently, in mapping both systems are used, which increases the accuracy and availability of mapping in extreme conditions (GLONASS system significantly offset the deficiency of American NAVSTAR satellites, which lead to increase of accuracy and availability of GNSS technology in extreme environments such as forest.

The equipment on the GNSS basis, sometimes called GPS/GIS, is effective in data collection in forested areas, e.g. also in forest stand description (forest taxation), in forest detail object location and attribute collection in forestry thematic mapping (Tuček et al. 2002). These systems are used mainly for navigation on the ground and under canopy but LIDAR and IFSAR remote sensing technologies are equipped with GPS for obtaining accurate coordinate system of flying. At this time there is an effort to equip the new forest (wheeled skidder, track skidder) and agriculture technologies with GPS because of its navigation and monitoring abilities. GPS builds connections among map, image or digital database and real, physical location on the Earth surface. A possibility of usage of such equipment for tracing and navigation (from the map, plan or image to real conditions) is it's another important attribute (Tuček, Suchomel 2003).

• **Inertial navigation system –** Inertial navigation system uses gyros, which is able to maintain on long-term indication of the specified direction. Measurement is based on the spread of the laser pulse in very long convoluted coils into fibreglass. With the progress of the motion sensor there are also emerging inertial navigation systems operating on different principles. These systems consist of sets capable of very sensitive accelerometers measurement changes in the direction of motion sensor. This sensor works in conjunction with a computer that continuously integrates the input signal of the accelerometers and determines the current location of the observed object. Inertial navigation is able to measure even in densely forested terrain, where other navigation may not work (Rapant 2002, Martinić et al. 2001).

• **Terrestrial Laser scanner** – Terrestrial laser scanning systems allows obtaining a large amount of data fast, called a point cloud. Point Cloud is a set of x, y, z coordinates and sometimes number of intensity, which after processing provides a 3D model of objects and terrain. Current researches are focused on forest inventory automation, for the derivation of forest stand and tree characteristics (height, diameter, round base, number of stem) and identification of the tree based on bark.

• **Laser Rangefinder Instrument** – The laser rangefinger is used for detecting distances and gradients between the instrument and an object. Principle of the laser rangefinder is based on laser beam, which is sent towards the object and measures the flight time of laser pulse reflected off the target. This tool is often combined with other device for example Fieldmap or video rangefinger instrument.

Figure 1 Laser Rangefinder Instrument.
Slika 1. Laserski daljinomjer.
(Source/izvor: http://www.laserrangefinderreviews.org/)

2.2. Airborne and satellite remote sensing technology as LIDAR (Light Detection and Ranging) and IFSAR (Interferometric Synthetic Aperture Radar) – *Tehnologije zračnog i satelitskog daljinskog istraživanja kao LIDAR I IFSAR*

These technologies have significant advantages because they are capable of collecting highly detailed data quickly from a large area with varying conditions at repeated time intervals. LIDAR offers us many different data products such as digital elevation model grid, contours, raw point data and intensity image. From data of IFSAR we are able to obtain almost similar products like from LIDAR however Orthorectified Radar Imagery (ORRI) is very significant data product of IFSAR. These products are used in Hydrology Modelling, Flood Risk Assessment, Land Use and Land Cover Mapping, Earth Crust Deformation Monitoring, Riparian Studies and Forestry Mapping.

Mainly, LIDAR has an important role in precision forestry because of its accuracy and other advantages. Nowadays, it is one of the most used and researched new technologies in the world by which we have reached valuable and useful information related to Forestry Management and other branches as Shoreline and Beach Volume Changes, Flood Risk Analysis, Water-Flow Issues, Habitat Mapping, Subsidence Issues, Riparian Studies, Emergency Response, Transportation Mapping, Telecommunication Planning and Urban Development.

Other airborne and satellite remote sensing technologies enable us to acquire data from high spatial resolution images, multi-spectral and hyperspectral images. In general, the remote sensing technologies are fast, accurate and cost-effective sources of data.

2.3. Real-time process control scanners – *Procesni skeneri kontrole drva u realnom vremenu*

Tools of precision forestry which were previously mentioned provide information in real-time. They have hardware and software devices which can be used either directly in the forestry fieldwork (combination by GPS) or in the wood processing industry (sawmill). This group can be divided into tools for tree identification (RFID and Aroma tagging) and tools for wood material testing and measurement (UDD, CT).

• **RFID** (*Radio Frequency Identification*) – it is focused on identifying trees and timber via wireless means and on sensing properties of the tree/timber during the identification process. RFID is a tag on tree that can gather a wide variety of information about trees and wood in-situ and real-time (Wilson et al. 2001).

• ***UDD*** **(Ultrasound decay detectors)** – it is used to detect decay in trees. It measures ultrasound signal time of flight from the transmitter to the receiver across the diameter of a tree (Leininger et al. 2001).

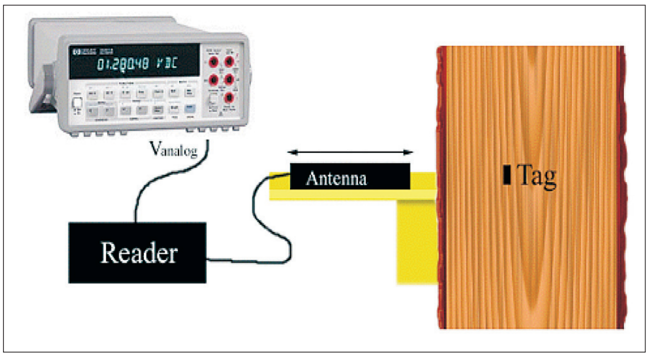

Figure 2 Wood material testing and measurement.
Slika 2. Ispitivanje i mjerenje drvnog materijala.
(Source/Izvor: Wilson et al. 2001)

• **CT (Computed tomography)** *Automated Log Grading System* – Computed tomography uses x-rays to produce high-resolution cross-sectional images of the internal structure of log (Rayner et al. 2001). The result is a defect map from the computed tomography data.

• **FieldMap –** World-wide, Fieldmap is very useful tool for forest inventorying, which computes field data collected during fieldworks. This device consists of hardware set like Electronic compass, optical scope, laser rangefinger, field computer, GPS, inclinometers and software divided into two main parts FM Project Manager and FM Data Collector. For data analysis there is used FM Inventory Analyst and FM Stem Analyst. FieldMap is used for forest structure mapping, long-term monitoring, descrtiption of forest stand, dendrometry measurements (<u>tree</u> height, <u>crown</u> projection and profile, <u>stem</u> profile, estimation of volume of <u>timber</u>), assessment biomass and growth stocks.

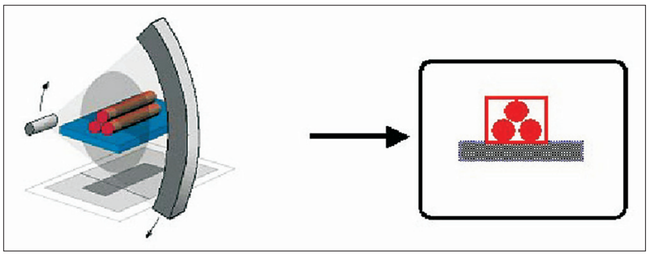

Figure 4 An automated log grading system.
Slika 4. Automatizirani sustav ocjenjivanja stanja debla/trupca.
(Source/Izvor: Rayner et al. 2002)

Figure 3 Using ultrasound to detect defects in trees.
Slika 3. Otkrivanje grešaka u stablu pomoću ultrazvuka.
(Source/Izvor: Leininger et al. 2001)

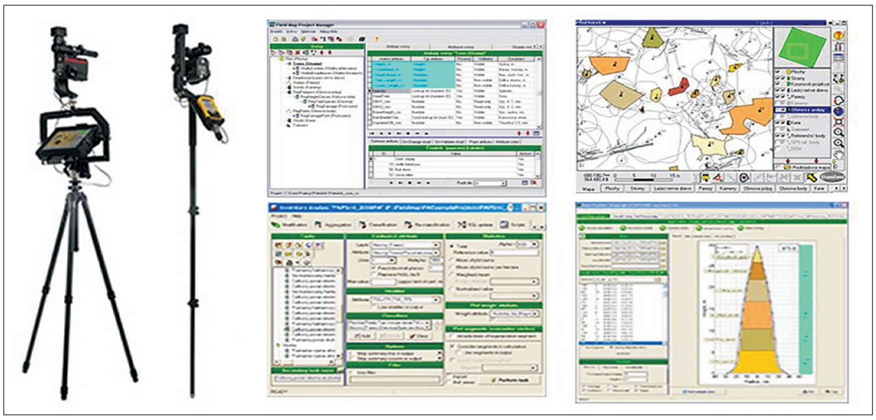

Figure 5 Source: http://www.fieldmap.cz/
Slika 5. Izvor: http://www.fieldmap.cz/

2.4. GIS (Geographic Information System) – *Geografski informacijski sustav*

GIS is a spatial information system that comprises out of four basic elements; hardware, software, data and user. By capturing, storing, checking, manipulating and analyzing the terrain information related to spatial and geographic distribution it can export all kinds of data and graphs, and provide a series of helpful documents and plans for the decision maker (Li et al. 2000).

This system can accommodate large amounts of data. GIS operates with variety of data types such as maps, images, digital products, GPS, text data and tabular data, all of which can be received from multiple sources. There is possibility to create large databases from gaining and measuring data which are joined with vector and raster formats. These outputs provide us specific images and maps such as Digital Elevation Models (DEMs), Digital Terrain Models (DTMs), Topographic Line Maps (TLMs), Contours, Shaded Relief, Slope & Aspect and Thematic Maps. The outputs are results of respective analyzes, such as Image analysis, Distance analysis, Spatial analysis, Geostatisticals analysis, Surface analysis, ect.

Related to other tools, GIS as software is very significant. This software can be integrated into handheld computers used for fieldwork and obtains information directly from outside. GIS has one important advantage – it is possible to create networks of GIS, which allows quick access to data and information.

2.5. DSS (Decision support systems) – *Sustavi za potporu odlučivanju*

They are specific software solutions, which have been developed for solving specific problems and offer forecast and factually information. Advantage of decision support systems is that it can be joined with GIS by which we can improve results. At present, there have been some decision support systems which dealt with predicting road networks, forest operation planning, forest inventory and others types of solutions. All of them are based on algorithms by which the solution and forecast is reached, and subsequently visualized.

In Slovakia at the Technical University in Zvolen there were OHTS (optimal harvesting and logging technology selection) model created, which were used for selection of optimal timber harvesting and logging machinery and technology; also FFRA model (Forest Fire Risk Assessment) is used for fire risk analysis which is significant part of the fire warning system. These DDSs were developed in NetWeaver environment and EMDS (Ecosystem Management Decision Support) environment and subsequently linked up with GIS.

• **OHTS** model is based on the assessment of ecological criteria like the terrain accessibility, the skidding distance, the erosion caused by logging, the cutting method, the soil capacity, the forest stand structure, the trucks loading places and on the assessment of economical and ergonomic criteria. The results of model assessment (digital or printed maps representing the appropriateness of each machinery/technology used on each forest stand), using the OHTS model, can be used by forest planners, mainly for operational and tactical planning of timber harvesting and logging activities in the forest (Tuček and Majlingová 2010, Suchomel and Balenová 2009).

• **FFRA** (*Forest Fire Risk Assessment*) model is based on existing methodology, which can be implemented to Decision support software. Methodology is based on two types of analyzes. In the first type, the forest fire risk is described by means of probability, the assumed disturbance of the forest (based on its species composition) in the age (t) during a common year. In the second type of analyzes, the influence of relevant geographic factors (elevation, slope, aspect, the nearest road distance, the nearest settlement and urbanized area distance) is tested against the fire occurrence. To use it, you have to acquire the data about burned out forest areas by processing records about fires in forest stands of the analyzed area in order to calculate the probabilities reporting the assumed disturbance of the forest. The results can be implemented also to forest management planning as a measure for reducing the vulnerability of the forest in the future. (Tuček and Majlingová 2010).

Among decision support systems file growth simulator software can be stipulated, which is implemented in forestry and ecology. In Slovakia there has been developed a growth simulator with entitled SYBILA which provides the advantage of an individual tree modelling approach. The model is able to predict forest development under the consideration of a wide range of input parameters. The growth simulator has already been successfully applied for the simulation of the impact of climate change and differently type of forest calamity on the development of Slovak forests (Fabrika et al. 2008). This model can be implemented into current forestry practice as a tool for decision support. Also, other European countries have some famous growth simulator software such as SILVA, MOSES, FOREST, STAND PROGNOSIS MODEL, BWIM and CORKFITS. These software solutions are very accurate and they have been constantly improved.

Precision forestry and all its tools provide many advantages to foresters, forest owners and wood processing industries and others.

Modern information technologies allow quick and direct communication among single forest operations. This allows reducing costs and increasing yield for forest enterprise and wood processing industry.

There are some disadvantages and problems with tools of precision forestry. One of them is that tools of precision forestry are not standard in all forest enterprises. Individual tools of precision forestry must be necessary combined in order to obtain more precise information, not only quantitative but also the qualitative aspects of the forest resource. The most common combination of tools are GIS, GPS and remote sensing technologies, which offer adequate resources of gaining precision data and additional accuracy of information used for decision. The other tools have narrow range of utilization and they are focused on specific field of forestry management. The next disadvantage is the price of some required data types which are significantly influenced by cost of tools operations and their accessibility. Tools of precision forestry are demanding mainly on hardware and some of them also software. Because of high demands on hardware, the acquisition costs are increased and tools are not reachable to all forest enterprise at the present.

All recorded data from tools is processed by suitable software and additionally necessary information is gained. Information has been recognized as being of similar importance as the basic production factors in producing enterprises. It plays an important role in planning, implementation and controlling production processes while supporting the management by providing relevant data on how to dispose of all relevant production factors (K ä t s c h 2006). There are some issues of information quality, mainly problems with poor accuracy, low precision, incompleteness and missing relevancy, all of which can be removed by combination and further development of tools of precision forestry. Obtained information from treated data can be used by all forest operations, wood processing industry and environmental protection professionals.

• Information for forest operations is used by selecting the suitable stand, harvesting operation, forwarding, storage and transport wood. Knowledge of information significantly influences planning, organization, control and duration of forestry works.

• For wood processing industry there is important information about wood as dimension, grade, grain, blight disease, stiffness and taper. This information influences production wood products thereby profitability wood industry.

• For environmental protection there is important information mainly about soil as erodibility, disturbance,

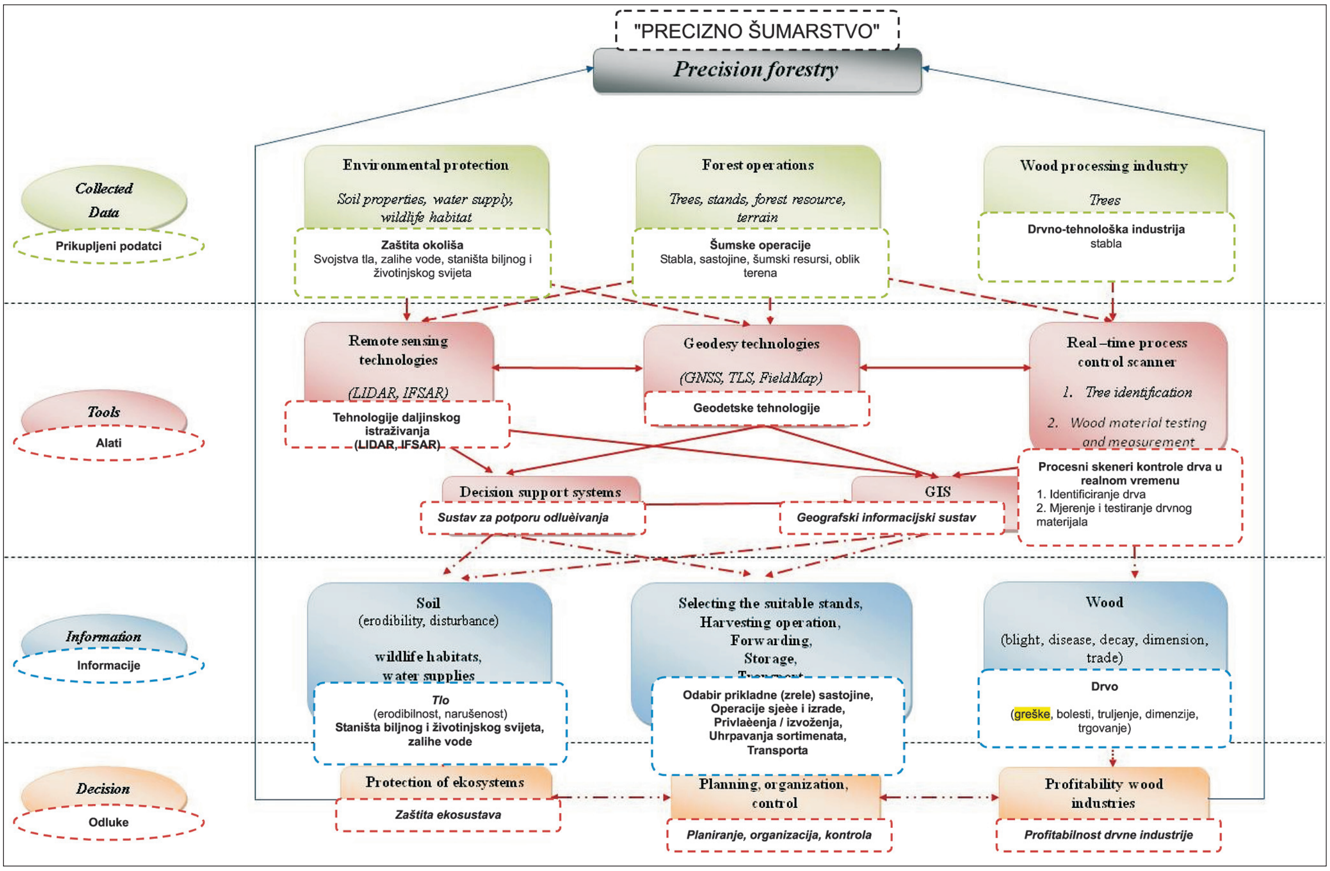

Figure 6 Diagram of Precision forestry.

Slika 6. Dijagram "preciznog šumarstva".

(Source/Izvor: Kovácsová, P. 2009)

compaction of soil and water supply as sedimentation, ditchwater. New information and knowledge have significant function in protecting rare ecosystem, parts of county as aquatic and wildlife habitats.

After perusing certain number of scientific material from conferences about precision forestry there was an explanatory diagram made showing the processes of precision forestry.

3. CONCLUSION – Zaključak

The term Precision Forestry is very debatable among researchers and variable definitions of Precision forestry depend on individual interpretation and understanding. The specific definition of the term precision forestry does not exist, while individual experts explain this term differently, but the principle of term remains essentially the same. In our opinion, the concept of "precision forestry" is that the use of modern tools and techniques to get as much real information as it is possible to improve decision making process and to ensure that current targets of forest management are met.

Precision forestry tools will help to make future operation more economically viable and to satisfy public and environment demands. This is important for sustainable management of forest and renewable resources. By idea of precision forestry we are able to improve productivity of forest, long-term planning, global and crop inventory, planning of road network (hauling road, skid trail), sustainable utilization of renewable resources and reducing negative environmental consequences.

Integration of precision forestry into Slovak forest management will have important meaning in the future. Quick progress of precision forestry aims to make technologies and accurate data accessible both to forest enterprise and to public. Additionally, every deficiency of forest management can be reduced or completely removed. This new direction of "Precision forestry" will bring modernization into not only Slovak silviculture.

In Technical University in Zvolen in Slovakia there were created Decision support system for Forest Fire Risk Assessment and for Optimal Harvesting Technology Selection (used EMDS) and Growth simulator SYBILA.

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SAŽETAK: Članak upoznaje znanstvenu i stručnu javnost s osnovnim informacijama vezanima za pojam “precizno šumarstvo”. Ovaj termin obuhvaća novi koncept šumarskog djelovanja koji se oslanja na moderne alate i tehnologije, s ciljem dobivanja što veće količine pravodobnih i korektnih informacija nužnih za sustav podrške pri odlučivanju. “Precizno šumarstvo” jednako je vezano uz zadovoljavanje aktualnih ciljeva gospodarenja šumama s ekonomskog, socijalnog i ekološkog stajališta, ali i s drvno-tehnološkog gledišta šireg šumarskog sektora. Od modernih tehnologija danas su u europskom šumarstvu najzastupljenije one vezane uz daljinska istraživanja i geografski informacijski sustav (GIS). U novije se vrijeme u mnogim područjima šumarske znanosti i prakse koriste različiti navigacijski sustavi. Novi globalni trend koji se sve više primjenjuje u poljoprivredi, odnosi se na sustav podrške pri odlučivanju – tzv. “Decision support system (DSS)”. Pojedine tehnologije navedenog sustava već su našle praktičnu primjenu u šumarstvu. Takvi su npr. alati za identifikaciju pogrešaka na sortimentima te instrumenti za testiranje i mjerenje drvnog materijala. Zbog svoje praktičnosti i pravovremenih informacija, postoji velik interes za primjenom tehnologija “preciznog šumarstva” u mnogim područjima operativnoga šumarstva.

Precizno šumarstvo koristi razne tehnike i alate koji se različito klasificiraju. U ovom radu klasifikacija je napravljena u 5 kategorija:

• Geodetske tehnologije (GNSS - globalni navigacijski satelitski sustavi) koje uključuju tehnologije za kartiranje šuma, inercijske navigacijske sustave, zemaljske laserske skenere i laserski daljinomjere, od kojih je jedan model prikazan na slici 1.);

• Avionske i satelitske tehnologije daljinskih istraživanja kao LIDAR (Light Detection and Ranging) i IFSAR (Interferometric Synthetic Aperture Radar);

• U realnom vremenu procesni skener za kontrolu drva (identifikacija radio frekvencijom na slici 2., ultrazvučni detektori propadanja drva na slici 3., kompjuterizirana tomografija na slici 4.);

• Geografski informacijski sustav (GIS);

• Sustav podrške pri odlučivanju koji je spojiv sa GIS-om.

• U Slovačkoj, na Tehničkom Sveučilištu u Zvolenu razvijeni su softverski sustavi podrške kod odlučivanja pod sljedećim nazivima:

• OTHS (Optimal harvesting and logging technology selection) – program za odabir optimalne tehnologije kod sječe i privlačenja/izvoženja) sortimenata;

• FFRA (Forest Fire Risk Assessment) – program za procjenu rizika od nastanka požara;

• SYBILA – softver za simulaciju rasta drveta koji se primjenjuju u šumarstvu i ekologiji.

Usprkos raznovrsnim definicijama pojedinih autora, koncept "preciznog šumarstva", prikazan u obliku dijagrama na slici 6., podrazumijeva planiranje i provođenje aktivnosti vezanih za različita stajališta gospodarenja šumom te operacije za poboljšanje kvalitete finalnih proizvoda od drva, iskorištenje drvnih resursa, smanjenje otpada, povećanje dobit i održavanje kvalitete okoliša.

Predviđanja su da će integracija "preciznog šumarstva" u bliskoj budućnosti u slovačkom šumarstvu voditi itekako važnu ulogu, posebice radi omogućavanja brze i izravne komunikacije između pojedinih šumarskih operatera s ciljem dobivanja pravovremenih i korisnih informacija za donošenje ključnih odluka. Posljedično, to će omogućiti smanjenje troškova i povećanje prihoda i profita i za šumarska poduzeća i za drvnu industriju.