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Multipurpose GIS Portal for Forest Management, Research, and Education

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Abstract: The main objective of this research was to develop a web-based geographic information system (GIS) based on a detailed analysis of user preferences from the perspective of forest research, management and education. An anonymous questionnaire was used to elicit user preferences for a hardware platform and evaluations of web-mapping applications, geographic data, and GIS tools. Mobile GIS was used slightly more often than desktop GIS. Web-mapping applications that provide information to the public and the present research results were rated higher than the forest management application. Orthophotos for general purposes and thematic layers such as forest stand maps, soils, protected areas, cadastre, and forest roads were preferred over highly specialized layers. Tools for data searching, map printing, measuring, and drawing on digital maps were rated higher than tools for online map editing and geographic analysis. The analysis of user preferences was used to design a new multipurpose GIS portal for the University Forest Enterprise. The GIS portal was designed with a three-tier architecture on top of the software library for managing user access, working interactively with digital maps, and managing web map applications. The web map applications focus on tools and geographic information not available elsewhere, specifically timber harvest and logistics, research plots, and hunting game management.

Keywords: GIS; web; user preferences; map portal; collaboration; forestry; education; research; operations

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1. Introduction

Geographic information about forest ecosystems is complex and requires coordinated collection, management, and processing [1]. Detailed and up-to-date geographic information is needed for long-term sustainable forest management. The Internet offers new opportunities for the creation and publication of digital maps and related services. Web-mapping portals provide interactive digital maps and ready-to-use tools for geographic data collection and analysis. A geographic information system (GIS) can be used for forest enterprise management [2], forest road planning [3,4], wildfire mapping and prevention [5,6], timber harvesting [7], and reforestation [8]. Online editing tools allow foresters to update data daily. Spatial decision support systems help minimize the negative impacts of forestry on the environment and maximize the benefits of forest ecosystem services.

Geoinformation has been used in forestry research to model and analyze spatial phenomena and relationships. A GIS was used to study the range of brown bears [9], bark beetle outbreaks [10], the spatial distribution of forest productivity rates [11], and the probability of wind- and snow-related damage to forest stands [12]. Mobile devices [13,14], autonomous ground vehicles [15], and unmanned aerial systems [16,17] have been tested for 3D forest mapping. Timely and comprehensive information can be obtained from high-resolution satellite imagery [18,19], close-range photogrammetry [20,21], and terrestrial laser scanning [22,23].

In addition, the GIS is widely used in forestry research and management. Therefore, forestry students need to acquire skills related to geographic data acquisition and processing. Young foresters need to have at least basic computer skills, the ability to use global navigation satellite systems (GNSS) to determine positions, and knowledge of digital mapping [24–26]. Geographic models also accelerate students' understanding of local and global forestry, renewable natural resources, and environmental issues [27,28].

Teachers and students prefer digital maps to traditional paper maps [29]. According to [30], teaching with web mapping is limited by learning objectives, course scope, topics covered, software availability, and information technology support. Web mapping can be integrated into curricula as a stand-alone subject or as part of a related subject. Teaching spatial awareness and web mapping is preferred over technical and programming skills.

The University Forest Enterprise of the Technical University in Zvolen (UFE) in central Slovakia manages 9724 ha of forest for research and educational activities. Outdoor facilities serve as forestry laboratories and demonstration areas for silviculture, dendrology, forest inventory, wildlife management, logging, and transportation. The enterprise, a workplace for students, researchers, and forestry professionals, applies naturalistic forest management based on the latest forestry science.

Digital maps, geographic data, and knowledge sharing are needed to link forestry, research, and education, and the web-based GIS is a powerful, sophisticated multi-user means for disseminating geographic information. The GIS tools needed by students, researchers, and foresters are likely to be different because of different goals, knowledge, and working backgrounds. One challenge to implementing a web-based GIS is the integration of geographic data and specialized GIS tools to support forestry education, research, and management activities.

This paper presents the results of a user requirements analysis for the web-based UFE GIS. The original vision of the multi-purpose GIS portal was presented using the prototype. From an anonymous questionnaire, data were collected and statistically analyzed to investigate the requirements of the different target groups (foresters, forest scientists, teachers, and students) for geographic data and GIS tools. Users were given unrestricted access to the web mapping applications and rated the importance of the web GIS functions in relation to their needs. The relative importance of GIS tools, geographic data, and web mapping applications was considered in the final design of the multipurpose GIS portal for forestry, forest research, and education.

2. Materials and Methods

2.1. Prototype of the GIS Portal

The prototype was developed from scratch using the results of studies on spatial-decision support, participatory forestry approaches, and web-mapping applications [31–33]. Its main goal was to test the concept of the GIS website and to give potential users an overview of its possibilities; but was not intended for future use or maintenance. It consisted of five specialized web applications made available to users through the GIS portal:

1. Public Maps provides detailed interactive online digital maps of the UFE area, including roads, color orthophoto maps, and thematic maps of forest stands for public use.
2. Forest Management presents forest stand maps using a combination of orthophoto time series, high-resolution digital elevation models (DEMs), and digital surface models (DSMs).
3. Timber Harvest and Logistics is highly specialized and provides detailed information on the forest road network, landings, skidding distances, and forest stand terrain.
4. Hunting Game Management gives detailed maps of roads and trails, hunting lodges, stands, game feeders, wild boar parks and other hunting facilities. It also calculates viewing areas from user-defined points, including 3D visualization.
5. Terrestrial Laser Scanning (TLS) and Close Range Photogrammetry (CRP) focuses on new data sources for forest inventory, growth forecasting, and 3D modeling. The location of research plots and research activities is included. Point clouds are published and visualized in interactive 3D views.

The prototype of the web-based GIS was created in a simple three-tier architecture (Figure 1) to avoid extending the development time for the final version. To make the prototype applications easily modifiable, each had its own database table and graphical user interface. The prototype applications reflected the key features and aspects of the planned web-based GIS. Vector, raster, and image data were stored in a Microsoft SQL Server 2008 geodatabase. The map web services and web applications were built on ArcGIS for Server from Esri [34], and web applications were developed for Microsoft ASP.Net Framework in C# and Model-View-Controller (MVC) architecture. The open-source libraries jQuery [35] and Bootstrap [36] were used to create the graphical user interface. The web map services for topography, soil, parcels, and protected areas provided by national mapping agencies were also used in the web mapping applications. The prototype was used to determine the requirements of the user groups and was then discarded.

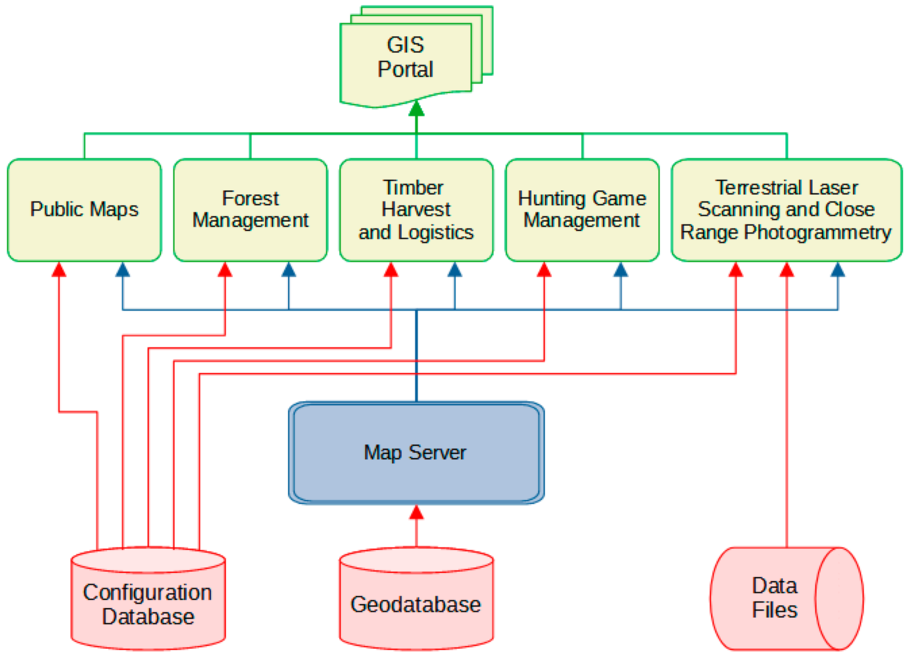

Figure 1. Architecture of the web-based GIS prototype.

2.2. User Preferences

For preference analysis, data were collected from four groups of users: students, researchers, foresters, and teachers involved in forestry, research, and education.

Master's students from the adaptive forestry and the geoinformation and mapping technology in forestry programs were asked to complete the questionnaire. The students had backgrounds in geoinformatics, geodesy, and forestry. The researchers were PhD students, post-doctoral students, professors and researchers from the Technical University in Zvolen, the National Forestry Center in Zvolen or the Institute of Forest Ecology of the Slovak Academy of Sciences, which actively uses GIS in its research. Foresters from the UFE, the State Forestry Enterprise of the Slovak Republic and private forestry enterprises also evaluated the functionality of the web-based GIS. Its suitability for teaching students was evaluated by teachers from the Technical University. Each respondent evaluated all functions of a web-based GIS prototype for usability in their work.

Participants were recruited through personal contacts, e-mail and online social networks. Only participants who worked in forest research, education, or management were eligible. Preferences were collected from a total of 120 participants—30 from each target group. The average work experience in forestry was 7.4 years for researchers, 10.7 years for teachers, and 11.2 years for foresters. Regarding education, 32 had a bachelor's degree in forestry, 50 had a master's degree, 37 had a doctorate, and one had a master's degree in a field other than forestry.

Respondents were informed of the main objectives of the study and asked to complete an anonymous online questionnaire based on the data sources and tools implemented in the GIS prototype and planned for the next version. First, the platform part of the questionnaire asked about the use of GIS on desktop and mobile devices. Second, the importance of specialized web-mapping applications, geographic data sources, and geographic analysis tools was rated on a four-point cale. A neutral option was intentionally omitted to encourage respondents to make specific decisions. Respondents were asked to rate the features of the prototype from the perspective of their work or learning activities. The importance of the thematic layers and the GIS tools in the web mapping applications were also evaluated. Additional data sources and geographic tools that were not listed in the questionnaire could be entered in a free text field. Work experience in forestry, forestry educational background, and professional status (student, researcher, forester, or teacher) were also recorded for each respondent.

2.3. Data Processing

Respondents' preferences were evaluated separately for each user group. The data from the questionnaire served as input for statistical analysis using the program R [37]. Statistical hypotheses were tested with a significance level of 0.05.

The arithmetic mean and standard deviation of each rating were calculated for each target group and all respondents.

The normality of data distribution was tested using the Shapiro–Wilk test, and homogeneity of variance was tested using the Fligner–Killeen test. Because the statistical assumptions for analysis of variance (ANOVA) were not met, the Fisher–Pitman asymptotic permutation test with k-samples was used instead. Finally, paired Student's *t*-tests with Bonferroni corrections were used to detect statistically significant differences among user groups.

3. Results

3.1. User Preferences

The working prototype reflected much of the planned web-based GIS functionality. Users experimented with the prototype and suggested improvements according to their expectations and perceptions. Although implementation of the working prototype and the questionnaire survey prolonged the development of the web-based GIS, the user feedback provided valuable information for the development team when designing the final multipurpose GIS portal.

Most respondents had some experience with a desktop or mobile device GIS, reflecting the wide use of GISs in modern forestry. Mobile devices (e.g., phones and tablets) were used more frequently than desktop computers, especially among researchers (Table A1). It has been shown that a GIS is useful for forest navigation and data collection, and because it provides instant access to geographic data, accurate site surveying, and flexible data collection a mobile GIS a valuable tool for forest research. Mobile applications for timber harvesting, forest mapping, wildfire prevention, and logistics have been developed for use with a GIS [38–41] and are being used by foresters; in contrast, mobile GIS and global navigation satellite systems are only occasionally used in teaching, or in student activities, coursework, or final projects. However, no significant differences were found in the use of mobile devices among the target groups.

Significant differences were found in the use of desktop computers between students and the other user groups (Table A2). In this context they are typically used by researchers, foresters, and teachers to perform daily tasks such as creating forest inventory maps, processing collected data, and geographic analysis.

Respondents rated the specialized applications integrated into the map portal positively: students 67%, researchers 60%, foresters 73%, and teachers 77%. These applications precisely met the needs of users in forest research and management. Interactive searching, visualization, and data updating is done quickly and effectively with these specialized tools.

The modular architecture of the multi-purpose GIS portal also allows for the development and integration of additional web mapping applications based on future user requirements.

All user groups rated the Public Maps application highly (Figure 2, Table A3). These interactive digital maps are of interest to the public and helpful in planning sports and recreational activities on the UFE lands. The visually appealing maps are also an excellent way to promote the work of foresters and forestry research. No significant differences were found among user groups in their ratings of the public map application.

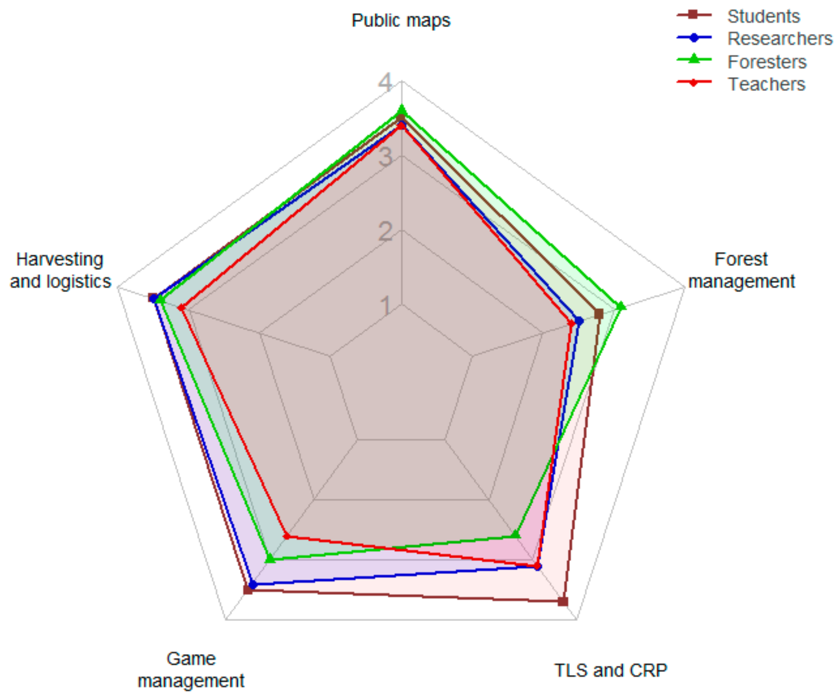

Figure 2. Importance of the web mapping applications (1—very low importance, 4—very high importance).

Students rated the Timber Harvest and Logistics application significantly higher than the teachers did (Table A4). Non-standard components such as the high-resolution DEM of the area, morphometric parameters, skidding distances, and user-defined, out-of-the-box extraction of elevation profiles were likely to be of interest to students.

The online hunting maps and tools were likely a source of new and interesting information for students and researchers (Table A3), they were less useful for foresters and teachers already familiar with the UFE area. In addition, information about hunting facilities is considered sensitive and could be misused for unauthorized camping, mountain biking, off-road riding, or poaching. Therefore, faculty ratings of this application were significantly lower than those of students and researchers (Table A4).

The TLS and CRP application was intended to facilitate the transfer of knowledge from forest science to practice and education. In fact, student ratings of the application were particularly high (Table A3), indicating their interest and openness to new knowledge and approaches in forestry and research. Students rated the TLS and CRP application significantly higher compared to researchers and foresters (Table A4).

The lowest rated application was Forest Management (Table A3), which is similar to the Forest GIS application developed by the Institute of Forest Resources and Information of the National Forest Center in Zvolen [42]. The Forest GIS is one of the main online sources of digital maps and information on forest stand characteristics in Slovakia and is usually accessed via desktop computers. Only 12 respondents had never used it. However, foresters rated the forest management application significantly higher compared to researchers and teachers (Table A4).

In general, ratings for base maps, orthophotos, and maps of forest stands and roads were higher than those for specific thematic layers related to forest management (Figure 3, Table A5). The fact that the layers related to forest stands were rated the highest indicates how important they are for forestry education, research, and management. This seems to contrast with the low rating for Forest Management, which is based on forest stand maps. This can be explained by the existence of different data sources: survey respondents preferred traditional and commonly used data sources; indeed, printed materials are still heavily used by foresters in the field.

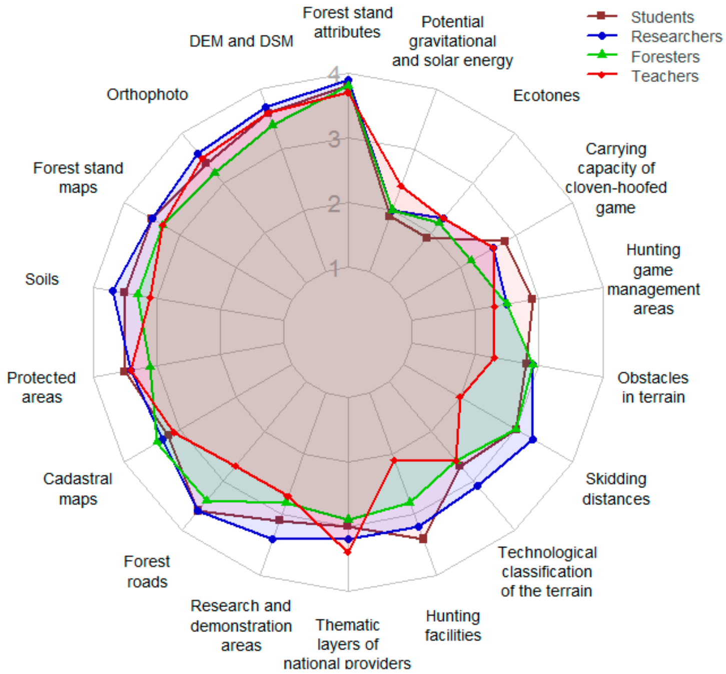

Figure 3. Importance of geographic data (1—very low importance, 4—very high importance).

The high-resolution DEM and DSM were derived from aerial photography data LIDAR. The resolution of the DEM and DSM rasters was 0.5 m. Many details, including old forest roads, trails, streams, tree canopies, and treetops, are clearly visible on the shaded models. The 130-channel 0.6-m resolution hyperspectral images from the UFE area and the 0.1 m color orthophotos are the result of previous research projects. All of these materials are valuable for forest mapping and inventory and were highly rated by the respondents. No significant differences were found among groups in the ratings of the forest maps and attributes, DEM, DSM, and orthophotos.

Teacher ratings for many specialized thematic levels were significantly lower than those of other respondents (Table A6). Online digital maps of forests and landscape features are relatively new, so teachers likely did not have enough time to research and incorporate them into their lectures.

No significant differences were found between student and researcher ratings. Both user groups are open to innovative approaches and showed great interest in the specialized and visually attractive thematic layers.

Foresters rated hunting facilities and game transport capacity significantly lower than the students did (Table A6). These differences reflected the ratings of the hunting game management application and confirmed that foresters demand strict protection of hunting game and facilities data.

Solar potential energy is an important input for models of forest growth and health. Potential gravitational energy was calculated to identify forest stands suitable for recuperative cableways. Potential gravitational and solar energy were of interest to only a few highly specialized respondents, which was consistent with the low ratings of these thematic levels.

Commonly used tools for spatial and attribute queries, printing maps, measuring lengths and areas, and importing and exporting data were rated highly by all target groups (Figure 4, Table A7). These tools can be easily used in many forestry research and management tasks. No significant differences were found among user group ratings.

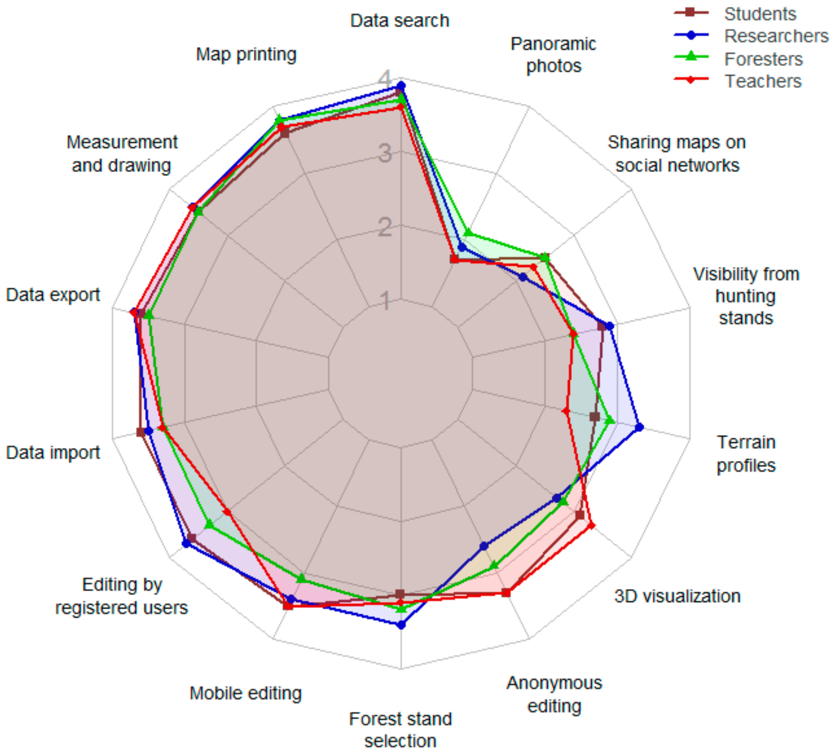

Figure 4. Importance of GIS tools (1—very low importance, 4—very high importance).

Students rated the tools for collecting and updating geographic data highly (Table A7). There is great potential for the use of editing tools in forest geoinformatics education. Regardless of the usefulness of the tools, teacher ratings were significantly lower than students' (Table A8). In addition, anonymous editing was not valued by researchers because their attitudes may have been influenced by the need for accurate, validated data.

Teachers valued the use of mobile devices and 3D visualizations of forests and landscapes, which were also attractive to students (Table A7). Computer-assisted learning, multimedia, and publishing of classroom materials on the Internet facilitated time- and place-independent and lifelong learning.

Tools for hunting and sharing maps and photos on the Internet were rated low (Table A7), which is consistent with the low ratings for the Hunting Game Management web application (Table A3) and hunting facilities data (Table A5).

3.2. Design of the GIS Portal

The final GIS portal was also designed with a three-tier architecture and on the same technical basis as the system prototype (Figure 5). However, it was developed as a unified solution for all map applications. A library of reusable object classes for managing user access rights, tools for interactive work with digital maps, and a unified system for creating and managing web map applications were created.

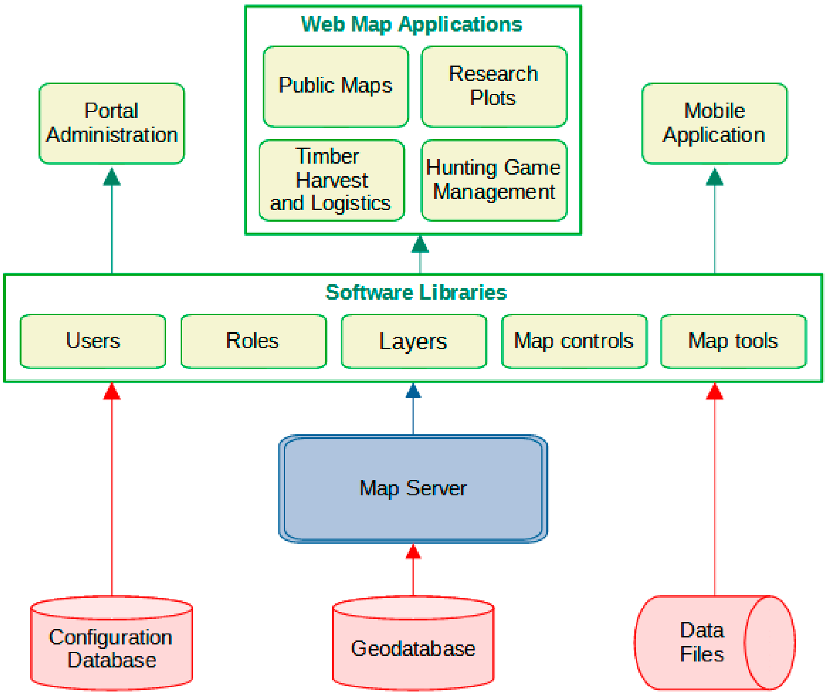

Figure 5. Architecture of the GIS portal.

We introduced five standard user groups: public, students, researchers, staff, and administrators. Public users can only view public layers. Future enhancements to the GIS portal may include making additional thematic layers available to registered users. Students have access to almost all UFE data for their studies and work. Researchers and staff can update thematic layers, such as research areas, hunting facilities, logging points, forest roads, and streams. Portal administrators have access to tools for managing users, map services, and for map web application templates.

Map web applications are not programmed separately in the portal solution, but are generated from their descriptions stored in the system's configuration tables. Based on a survey of user preferences, four main map web applications were configured in the GIS portal (Figure 6). Forest Management was discontinued because users prefer the standard Forest GIS application from the National Forest Center to obtain detailed information about forest stands [42]. The functions of the TLS and CRP application from the prototype GIS portal were transferred to the new Research Plots application, which provides a detailed map of research areas, demonstration objects and the results of selected research projects.

GIS tools are expected to accelerate and facilitate forest research and management with geographic data. A wide range of tools can be implemented in web mapping applications that support interactive map compilation and editing, online manipulation of geographic data, spatial and attribute queries, and complex geographic analysis or predictive modeling.

The map web application template consists of several configurable components (Figure 7). The system administrator can modify the components of existing web applications and create new map applications from the available map controls, tools, and web services. The module for mobile-device GISs has been designed so that the application can adapt to mobile devices.

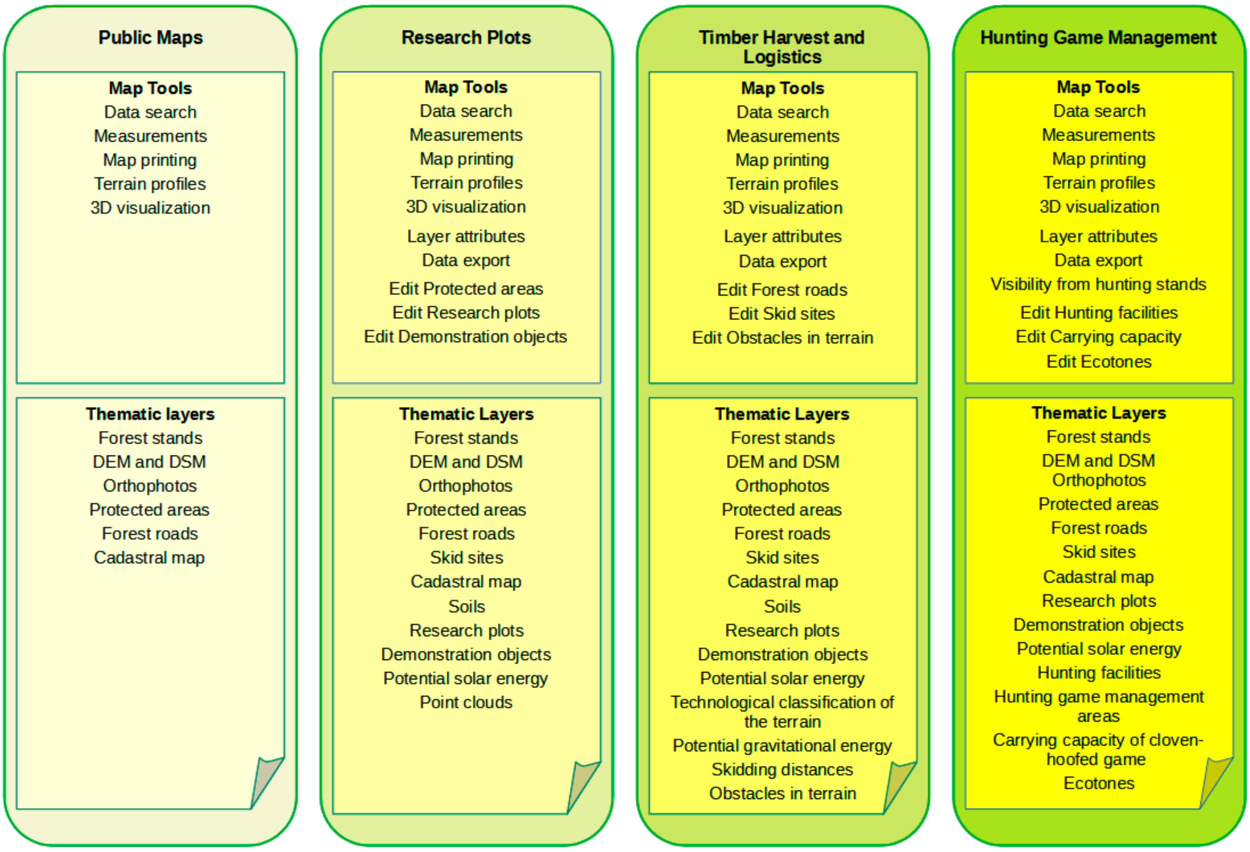

Figure 6. Schematic diagram of the web map applications.

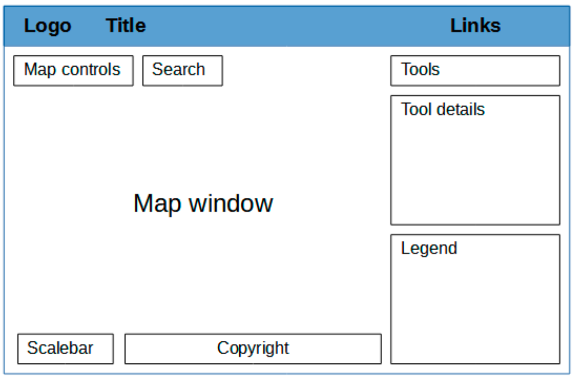

Figure 7. Template of the web map application.

4. Discussion

The multipurpose GIS portal can be used in lectures as well as in forestry practice and research projects, while the authors of other studies mostly focused on specific solutions. Vahidi et al. [43] developed a GIS for mapping urban trees based on remote sensing data and field data collected by volunteers. A web portal for standardized information management of research sites was developed by Wohner et al. [44]. A web-based interface and framework for high performance scientific computing was proposed and successfully tested by Moreno et al. [45]. Athanasiadis and Andreopoulou [46] implemented a rule-based web decision support system to automate land characterization and increase forester productivity. The main challenge in the development of the multi-purpose web GIS is the integration of the different functions needed by students, teachers, researchers and foresters. Therefore, the functions of the web-based GIS were rated by users using preference questions on a Likert scale and then statistically analyzed to determine the relative importance of client hardware platforms, GIS tools, thematic layers, and specific web applications.

Some raster layers of the proposed GIS portal were the result of extensive spatial modeling by external procedures. For example, skidding distances must be recalculated after each update of the forest road network and skid point locations.. The calculation of skidding distances is time consuming and the administrator had to import the resulting raster layers into the geographic database and update the web-mapping services. A more effective solution would have been to implement spatial modeling using the OGC Web Processing Service, which allows dynamic data exchange and integration of environmental models [47].

The general public may also be interested in ecological issues, sports, or recreational activities on forest lands and may have their own preferences for data sources, mapping features, and user interfaces. However, our study focused primarily on the needs of forest professionals, so the needs of the general public were not considered. The participatory GIS has proven to be an effective tool for single tree mapping, ecosystem services, public participation in forest planning, and natural disaster risk management [48–50]. The current version of the web-based GIS does not allow for active public participation; this should be considered in future development.

Janse and Konijnendijk [51] pointed out the weaknesses of the GIS as a communication tool for decision support in forest management. Thematic maps are not easily understood by a wide audience, so GIS tools are often perceived as complicated and inflexible during routine work. Therefore, the graphical interface of a web-based application must be intuitive and its tools must be well suited for specific tasks. However, a multi-user web mapping application must include common tools for interacting with digital maps and managing user roles. The effectiveness of the graphical user interface is influenced by the layout of the web page, the graphical design of the controls, and the capabilities of the device [52]. A minimalist web design was used for web-mapping applications. The layout of the web pages was simplified; the number of graphical user interface elements was reduced, and the web mapping applications were highly customized to user preferences.

Because teachers are usually involved in research, the same person could use the web-based multipurpose portal GIS for education and research at the same time. In the survey, it was not possible to identify respondents who might have completed the questionnaire as both a teacher and a researcher because anonymity was necessary to ensure the objectivity of the responses. However, all respondents were informed in detail about the specific perspective from which they were to evaluate the GIS portal.

5. Conclusions

The study found significant differences in the requirements of different user groups for some components of the web-based GIS. In general, students were very open to new technology and learning approaches. The web-mapping applications give students access to real geographic data on forest stands and facilitated close engagement with forest research and management. Online maps and geographic analysis tools helped explain and understand important forestry topics.

The students had limited knowledge of geoinformatics, which included entering and processing geographic data, working interactively with digital maps, and basic geographic analysis. On the other hand, teachers were constrained by the curriculum, appropriate GIS tools, geographic data, and time. Because of these limitations, they were reluctant to adopt new learning materials and technology.

Finally, the validity and protection of sensitive data about forest stands and hunting was very important for researchers and foresters. Therefore, while interactive digital maps are an appropriate medium for presenting the UFE to the public, they had to be limited to non-sensitive thematic layers. In addition, existing national forestry web mapping applications are well known to users, so the GIS portal should not duplicate their functions. The GIS portal improves communication and coordination among students, researchers, faculty, and foresters as online access to geographic data improves the quality of forestry education and collaboration between research and management. Customized web-mapping applications improved the collection, processing, and availability of forestry information and promoted better coordination of forestry research, management, and education.

The results of the study were used to develop a new web-based multipurpose GIS to support teaching, learning, research, and management in all areas of forestry. The web-mapping applications integrated into the multipurpose GIS portal had a common geographic database, user management subsystem, GIS tools, and other software components. The components of the web-based multipurpose GIS framework were reusable for integrated web mapping applications, and sharing the functions of the web-based multipurpose GIS framework among multiple web-mapping applications made the applications more user-friendly. The modular architecture of the web-based GIS increases the complexity of the framework and maintenance as additional functions are required to integrate the applications.

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Appendix A

Table A1. Use of GIS platforms.

Platform	S [1]	R	F	T	A
Desktop	2.7 ± 0.6	2.5 ± 1.1	2.6 ± 1.1	2.4 ± 0.9	2.3 ± 0.9
Mobile	2.2 ± 0.9	2.9 ± 1.0	2.6 ± 1.0	2.5 ± 0.7	2.6 ± 0.9

[1] S—students, R—researchers, F—foresters, T—teachers, A—all respondents, 1—not used, 2—rarely used, 3—frequently used, 4—regularly used, arithmetic mean ± standard deviation.

Table A2. Significant differences in desktop computer use between students and the other user groups.

User Groups	Difference	*p*-Value of *t*-Test
Researchers/students	0.8	8.3×10^{-3}
Foresters/students	0.9	3.4×10^{-3}
Teachers/students	0.7	4.4×10^{-2}

Table A3. Importance of the web mapping applications.

Application	S [1]	R	F	T	A
Public Maps	3.5 ± 0.6	3.4 ± 0.7	3.6 ± 0.7	3.4 ± 0.5	3.5 ± 0.6
Timber Harvest and Logistics	3.5 ± 0.6	3.5 ± 0.9	3.4 ± 0.6	3.1 ± 0.5	3.4 ± 0.7

Table A3. *Cont.*

Application	S [1]	R	F	T	A
Hunting Game Management	3.5 ± 0.5	3.4 ± 0.9	3.0 ± 1.0	2.6 ± 0.6	3.1 ± 0.7
TLS and CRP	3.7 ± 0.5	3.1 ± 0.9	2.6 ± 1.1	3.1 ± 0.7	3.1 ± 0.8
Forestry	2.8 ± 0.9	2.5 ± 1.1	3.1 ± 1.0	2.4 ± 0.6	2.7 ± 0.9

[1] S—students, R—researchers, F—foresters, T—teachers, A—all respondents, 1—very low importance, 4—very high importance, arithmetic mean ± standard deviation.

Table A4. Significant differences in web mapping application scores by user group.

Application	User Groups	Difference	*p*-Value of *t*-Test
Timber Harvest and Logistics	Students/teachers	0.4	4.0×10^{-3}
Hunting Game Management	Students/teachers	0.9	8.7×10^{-5}
	Researchers/teachers	0.8	6.1×10^{-4}
TLS and CRP	Students/researchers	0.6	2.8×10^{-3}
	Students/foresters	1.1	7.0×10^{-6}
Forestry	Foresters/researchers	0.6	4.4×10^{-3}
	Foresters/teachers	0.7	5.1×10^{-3}

Table A5. Importance of geographic data.

Thematic Layer	S [1]	R	F	T	A
Forest stand attributes	3.8 ± 0.4	3.9 ± 0.4	3.8 ± 0.4	3.7 ± 0.5	3.8 ± 0.4
DEM and DSM	3.6 ± 0.7	3.7 ± 0.6	3.4 ± 0.6	3.6 ± 0.5	3.6 ± 0.6
Orthophoto	3.4 ± 0.7	3.6 ± 0.7	3.2 ± 0.8	3.5 ± 0.5	3.4 ± 0.7
Forest stand maps	3.5 ± 0.6	3.5 ± 0.6	3.3 ± 0.7	3.3 ± 0.7	3.4 ± 0.7
Soils	3.5 ± 0.6	3.7 ± 0.5	3.3 ± 0.8	3.1 ± 0.6	3.4 ± 0.6
Protected areas	3.5 ± 0.6	3.4 ± 0.8	3.1 ± 0.7	3.4 ± 0.6	3.4 ± 0.7
Cadastral maps	3.2 ± 0.7	3.3 ± 0.7	3.4 ± 0.7	3.1 ± 0.7	3.3 ± 0.7
Forest roads	3.6 ± 0.7	3.6 ± 0.5	3.4 ± 0.7	2.7 ± 0.6	3.3 ± 0.6
Research and demonstration areas	3.1 ± 0.7	3.4 ± 0.8	2.8 ± 1.0	2.7 ± 0.9	3.0 ± 0.8
Thematic layers of national providers	3.0 ± 0.7	3.2 ± 0.7	2.9 ± 0.9	3.4 ± 0.6	3.0 ± 0.7
Hunting facilities	3.4 ± 0.7	3.2 ± 0.8	2.8 ± 1.0	2.1 ± 0.8	2.9 ± 0.8
Technological classification of the terrain	2.7 ± 0.8	3.1 ± 0.8	2.6 ± 0.8	2.6 ± 0.7	2.8 ± 0.8
Skidding distances	3.0 ± 0.9	3.3 ± 0.9	3.0 ± 0.8	2.0 ± 0.6	2.8 ± 0.8
Obstacles in terrain	2.8 ± 0.6	2.9 ± 0.9	2.9 ± 0.8	2.3 ± 0.6	2.7 ± 0.7
Hunting game management areas	2.9 ± 0.9	2.5 ± 0.9	2.5 ± 0.9	2.3 ± 0.7	2.6 ± 0.8
Carrying capacity of cloven-hoofed game	2.8 ± 0.7	2.6 ± 0.8	2.2 ± 0.8	2.6 ± 0.5	2.6 ± 0.7
Ecotones	1.9 ± 0.8	2.3 ± 1.0	2.2 ± 0.7	2.3 ± 0.7	2.2 ± 0.8
Potential gravitational and solar energy	1.9 ± 0.7	2.0 ± 0.9	2.0 ± 1.0	2.4 ± 0.7	2.1 ± 0.8

[1] S—students, R—researchers, F—foresters, T—teachers, A—all respondents, 1—very low importance, 4—very high importance, arithmetic mean ± standard deviation.

Table A6. Significant differences in the geographical data rating by user group.

Thematic Layer	User Groups	Difference	*p*-Value of *t*-Test
Soils	Researchers/foresters	0.4	2.7×10^{-3}
	Researchers/teachers	0.6	3.9×10^{-5}
Forest roads	Students/teachers	0.9	7.1×10^{-7}
	Researchers/teachers	0.9	1.0×10^{-7}
	Foresters/teachers	0.7	6.5×10^{-5}
Research and demonstration areas	Researchers/teachers	0.7	5.5×10^{-4}
Hunting facilities	Students/foresters	0.6	4.8×10^{-3}
	Students/teachers	1.3	2.4×10^{-7}
	Researchers/teachers	1.1	4.3×10^{-6}
	Foresters/teachers	0.7	1.1×10^{-3}
Skidding distances	Students/teachers	1.0	1.1×10^{-5}
	Researchers/teachers	1.3	6.8×10^{-8}
	Foresters/teachers	1.0	4.4×10^{-5}
Obstacles in terrain	Researchers/teachers	2.6	1.5×10^{-3}
	Foresters/teachers	2.6	1.5×10^{-3}
Carrying capacity of cloven-hoofed game	Students/foresters	0.6	1.5×10^{-3}

Table A7. Importance of GIS tools.

GIS Tool	S [1]	R	F	T	A
Data search	3.8 ± 0.4	3.9 ± 0.3	3.7 ± 0.7	3.6 ± 0.5	3.8 ± 0.5
Map printing	3.6 ± 0.6	3.8 ± 0.6	3.8 ± 0.4	3.7 ± 0.5	3.7 ± 0.5
Measurement and drawing	3.5 ± 0.5	3.6 ± 0.6	3.5 ± 0.7	3.6 ± 0.5	3.6 ± 0.6
Data export	3.6 ± 0.6	3.7 ± 0.6	3.5 ± 0.6	3.7 ± 0.5	3.6 ± 0.6
Data import	3.6 ± 0.6	3.5 ± 0.7	3.3 ± 0.8	3.3 ± 0.6	3.5 ± 0.7
Editing by registered users	3.6 ± 0.6	3.7 ± 0.6	3.3 ± 0.8	3.0 ± 0.8	3.4 ± 0.7
Mobile editing	3.5 ± 0.6	3.4 ± 0.6	3.1 ± 0.9	3.5 ± 0.6	3.4 ± 0.7
Forest stand selection	3.0 ± 0.7	3.4 ± 0.7	3.2 ± 0.6	3.1 ± 0.4	3.2 ± 0.6
Anonymous editing	3.3 ± 0.7	2.6 ± 1.1	2.9 ± 0.8	3.3 ± 0.7	3.0 ± 0.8
3D visualization	3.1 ± 0.7	2.7 ± 0.9	2.8 ± 0.9	3.3 ± 0.5	3.0 ± 0.8
Terrain profiles	2.7 ± 0.9	3.3 ± 0.8	2.9 ± 0.9	2.3 ± 0.7	2.8 ± 0.8
Visibility from hunting stands	2.8 ± 0.9	2.9 ± 1.0	2.4 ± 0.9	2.4 ± 0.7	2.6 ± 0.9
Sharing maps on social networks	2.5 ± 1.0	2.1 ± 1.0	2.5 ± 1.1	2.3 ± 0.8	2.4 ± 1.0
Panoramic photos	1.7 ± 0.8	1.9 ± 1.0	2.1 ± 0.9	1.7 ± 0.5	1.8 ± 0.8

[1] S—students, R—researchers, F—foresters, T—teachers, A—all respondents, 1—very low importance, 4—very high importance, arithmetic mean ± standard deviation.

Table A8. Significant differences in GIS tool ratings by user group.

GIS Tool	User Groups	Difference	*p*-Value of *t*-Test
Editing by registered users	Students/teachers	0.6	1.3×10^{-3}
	Researchers/teachers	0.7	6.4×10^{-5}
Anonymous editing	Students/researchers	0.7	2.1×10^{-3}
	Teachers/researchers	0.7	1.3×10^{-3}
3D visualization	Teachers/researchers	0.6	1.2×10^{-3}
Terrain profiles	Researchers/students	0.6	2.2×10^{-3}
	Researchers/teachers	1.0	4.7×10^{-5}
	Foresters/teachers	0.6	3.5×10^{-3}

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