A survey on the use of GIS and remote sensing for sustainable forestry and ecology in Russia and China

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There is an increasing international trend towards using powerful geospatial technologies such as geographic information systems (GIS) and remote sensing (RS — Earth observation data) (GIS&RS) in various applications. The Erasmus+ SUFOGIS project proposes a "knowledge-competence-skills based" innovative approach that is being developed in close collaboration between Russian, Chinese and EU partners. This paper focuses on a comparative analysis of the findings of two separate national surveys conducted by SUFOGIS partners in Russia and China, on the uptake and use of GIS&RS in the fields of forestry and ecology. From the analysis of the questionnaires and considering the type of institution from which the respondents come from, two main categories were identified: academic institutions (universities, colleges and research institutes) and companies (governmental and private). The results of the survey clearly demonstrate widespread use of GIS&RS in both non-EU countries and relatively high rate of expertise of the respondents. However, it was also found that there is still significant room for improvement in the use of GIS&RS in both countries. Examples are exploration of their integration into even more forestry and ecology applications as well as training of staff on advanced and specialized topics.

Keywords: GIS, remote sensing, forestry, survey, environment, Erasmus+, Russia, China

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Introduction

As early as the 1980s, the global community began to recognize that forests play a global role in biosphere stability, biodiversity conservation, erosion control, the protection of endangered indigenous and traditional cultures, and the provision of unique ecosystem services (The State..., 2018). Forests have also been identified as unique carbon sinks that play a very important long-term and lasting role in reducing the effects of climate change (Carbon..., 2005). Since then, the recognition of the importance of forests for sustainable development has been steadily increasing in most countries of the world, including the Russian Federation (Russia) and the People's Republic of China (China).

Forests in Russia cover about 815 million ha, which accounts for more than 20 % of the world forest area. In fact, it should be noted that in recent years the area covered by forests has increased by 20 million ha due to the reforestation of abandoned agricultural lands (http://www.fao.org/countryprofiles/index/en/?iso3=RUS). In China, huge areas are also covered by forests. China's 208 million ha of forest rank fifth in the world and account for 5.5 % of the world's forest cover (http://www.fao.org/countryprofiles/index/en/?iso3=CHN). It should be noted that in the past 40 years, forest cover

in China has increased from 12.00 to 22.96 %, the forest stock volume has increased by 8.5 billion m^3. Having the largest and fastest growing forest plantations, China is becoming the country with the largest growth in forest resources worldwide.

Proper management of forest resources is only possible when it is based on accurate and reliable information. There is an increasing international trend towards the use of powerful and flexible geospatial technologies such as geographic information systems (GIS) and remote sensing (RS) data (satellite imagery) (GIS&RS) in various applications (Chen, 2002; Van Trung, Tam, 2018). For example, the aforementioned tools have proven to be particularly important for monitoring and assessing the extent, structure, value and health of forests (Gong et al., 2017; Hamdi et al., 2019). GIS&RS data are commonly used for successful Land Use/Cover Change (LUCC) classification (Czerwinski et al., 2014; Jia et al., 2014), for estimating forest biomass at multiple scales with large spatial and temporal coverage (Chen et al., 2016; Galidaki et al., 2017), as well as monitoring land-cover changes in urban areas (Carlan et al., 2020; Gong et al., 2011).

Meanwhile, GIS&RS and their potential applications in forestry and ecology are not yet fully exploited in Russia and China, comparing to the EU countries. There are several reasons, common for the two countries, that explain this situation including: the on-going reforms in the forestry complex/ecology sector (counting education), the current gap in knowledge transfer between higher education institutions (HEIs) and enterprises, and the fact that sustainable management of the huge and remote forest areas of Russia and China are inherently difficult.

Going through the recent history of the two partner countries it is easy to recognise some common characteristics. Starting from the late 1980s, the specific countries went through deep political and economic reforms. As a result, sustainability is one of the most important issues in their current national and international agenda. Their focus on sustainable forestry and ecology is clearly reflected in several state documents such as the "The Russian Federation forest sector outlook study to 2030" (The Russian..., 2012), and the "National Strategies for Sustainable Development" as they are published by the governments of the two countries.

SUFOGIS is an Erasmus+ Capacity Building project involving universities and organizations from the European Union, Russia and China and whose central idea reflects the above considerations (GIS and Remote Sensing for Sustainable Forestry and Ecology, https://sufogis.volgatech.net/). Its main rationale is to create a support structure for GIS&RS innovations and their application in forestry and ecology that not only connects knowledge in an interdisciplinary way, but also brings together three critical scopes: practical forest/ecology and business (enterprises), policymaking (Local ministries) and science (Institutes, HEIs). SUFOGIS proposes a "knowledge-competence-skills based" innovative approach that will be developed in close collaboration between all partners.

During the preparation phase of the project, Russian and Chinese HEIs consortium in cooperation with associated partners carried out a survey on the use of GIS&RS techniques and compliance of graduate student competences to the required standards of such specialists in EU countries. The importance of the carried out SUFOGIS survey was in unbiased approach to decision-making by the project partners for the promotion GIS&RS technologies and retraining of the target groups in Russia and China. The main research tool used in this study was a questionnaire designed to collect and analyze information on the target groups' GIS&RS experience in different parts of both countries.

The main aim of this paper is to explicitly present and discuss the results of the online questionnaire. Subsequently, these results are gathered to give a concluding review of the state of the use of GIS&RS and to outline the target group's requirements for future developments in the forestry and ecology sectors of the SUFOGIS partner countries.

Materials and methods

An analysis was designed to measure the needs of the academia and industrial stakeholders in the GIS&RS technologies in Russia and China. The needs assessment includes internal environment such as required and needed competences of staffs and students, existing courses, projects, and infrastructure while specific environment includes labour market, staff development, and internet infrastruc-

ture. To evaluate the needs of SUFOGIS project, main stakeholders (target groups) in both countries in the field of forestry and ecology were identified based on relevance to technology or possibility to apply in their future work. Ultimately, stakeholders have been identified as two main categories: academia (universities, colleges and institutes) and enterprises (governmental and private).

The main research tool used in this study was a questionnaire designed to collect and analyze information about the target groups GIS&RS experience in different parts of Russia and China. In order to study the existing experience and prospects of using GIS&RS in science and practice, the SUFOGIS partners have carried out the survey for stakeholders employed or enrolled in forestry and environment sectors. Academic staff from selected universities, colleges and professional staff from enterprises were requested to answer the questionnaires, which would give new insights into the project development and extensions. Respondent organizations were selected based on relevance in using of GIS&RS technologies or possibility to apply them in their future work. The SUFOGIS national questionnaire surveys, in total consisting of 24 questions, thematically were divided into five parts:

1. Understanding demographic characteristics and affiliation of the survey participants (6 questions).
2. Identification of the field of forestry the respondent works in and their use of GIS and/or RS in sustainable forest management (5 questions).
3. Identification of the most used GIS&RS software products in the field of forestry and environment (4 questions).
4. Drawbacks in the use of GIS&RS in the forestry / environmental studies (3 questions).
5. Analysis of the target audience readiness to participate in the training in GIS&RS applications in sustainable forestry and ecology (6 questions).

The first two parts of the questionnaire mainly contribute to a better understanding of the target groups (gender, age, education level, etc.) and their professional affiliation. The third and fourth parts are specifically designed to identify how respondents in Russia and China used GIS&RS in their daily work activities. These include levels of expertise, software, data type and scale typically used. There are also 3 questions to find out any technical and/or data constraints that, in the opinion of the respondents are hindering the potential use of GIS&RS within their organisation or company. The fifth part of the questions places the overall answers in context to gauge the interest of survey participants in training programs offered by the project consortium partners (time, guidance, field and method of training). The SUFOGIS questionnaire presented in this paper is a combination of closed single answer questions; closed, multiple answer questions; semi-open questions and open questions. Such organisation of questions allows the respondents to go into more detail and add their own answer.

To bring the broad professional community of foresters, ecologists and environmentalists to the questionnaire, two online surveys were created. For Russian respondents the Survey Google and for Chinese respondents the QuestionStar online tools were used. By sending 1000 e-mails in both countries, the SUFOGIS consortium partners invited a wide range of possible respondents from universities, SMEs, ministries, NGOs, private companies, government agencies, forestry organizations and companies, research organizations and institutions all over the territories of both countries. The invitations to potential respondents briefly described the SUFOGIS project and survey rationale, approximate time to answer the questions, the incentive, and the importance of the activity. The SUFOGIS questionnaires were available for approximately 2 months between December 2018 and January 2019. Follow up e-mails and telephone calls by the consortium members increased the overall surveys response rate in both countries up to 20 %.

Results

The second stage of the SUFOGIS survey methodology followed the analysis of the completed questionnaires. Despite the rather large number of survey questions, 349 completed questionnaires in China were collected. Geographically the project survey answers came from Fujian, Beijing, Jiangsu, Zhejiang, Henan, Shandong, Yunnan, Hubei and Shanxi provinces. In the Russian survey,

the geographical distribution of the 470 respondents were mainly located in 28 big cities (*fig. 1*). However, 2 respondents were from other neighbouring countries, Belorussia (Minsk) and Kazakhstan (Almaty). In total, the final assessment was 819 respondents from the focus groups in China and Russia.

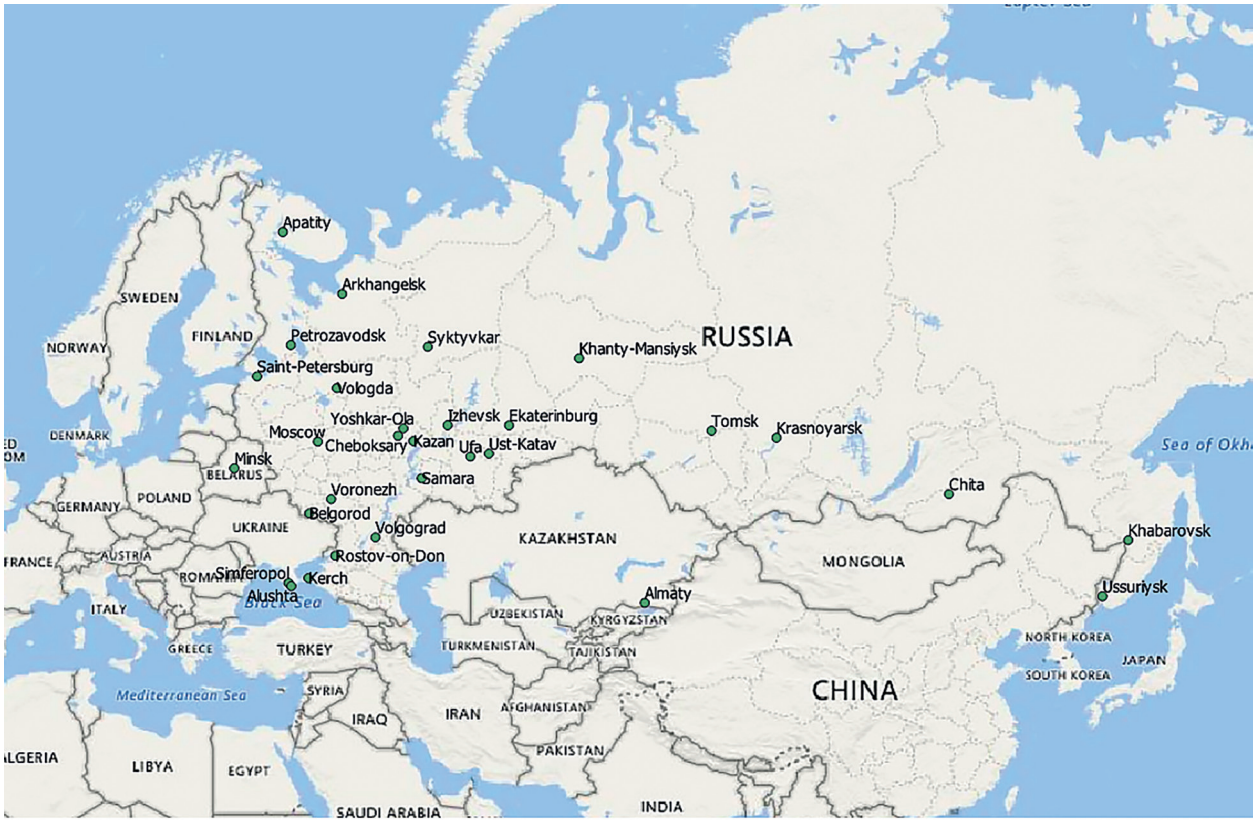


Fig. 1. Distribution of SUFOGIS survey responses through the Russian cities

Processing of the questionnaires showed almost the same gender balance of the survey participants with overrepresentation of male respondents (62.7 % in Russia and 62.2 % in China). Age was considered one of the main determinants that affects opinions and reactions of the respondents, therefore questionnaire survey was conducted among participants of different age groups (*fig. 2a*, see p. 13). A larger number of survey participants were young people under the age of 30 (37.5 % in Russia and 45.5 % in China) and citizens aged 31 to 40 (25.8 % in Russia and 32.1 % in China). It can be assumed that such figures of respondent age distributions are positive for the continuity and turnover of the personnel. However, the survey among practitioners in Russia showed that the number of young specialists in forestry enterprises is less than specialists from the group aged 51–60 (24 %), which indicates a low turnover of staff in forestry enterprises.

Of the 470 respondents in Russia, 95 participants (20 %) are students (*fig. 2c*), while the distribution by gender among them is fairly uniform. Among Chinese respondents, there are mainly students (43.2 %) and university teachers (31 %). Regarding the educational background in Russia (*fig. 2d*), the largest group (39.0 %) comprises people who have obtained a Specialist* degree, and the second largest group is those who have a Master degree (21.1 %). Among Chinese respondents, Master (34.3 %) and PhD (50.2 %) backgrounds prevail. Most of the respondents (65 %) work in academic organisations all over Russia (58 % in universities and 7 % in research organisations). Furthermore, 28 % of Russians work in governmental organisations (2.2 % in China), 5 % in private companies, and 3 % in

* A five-year higher-education diploma that was the only first higher-education diploma in the former Soviet Union.

NGO (*fig. 2b*). In contrast, Chinese respondents are mainly from universities (76.9 %) and research institutions (16 %).

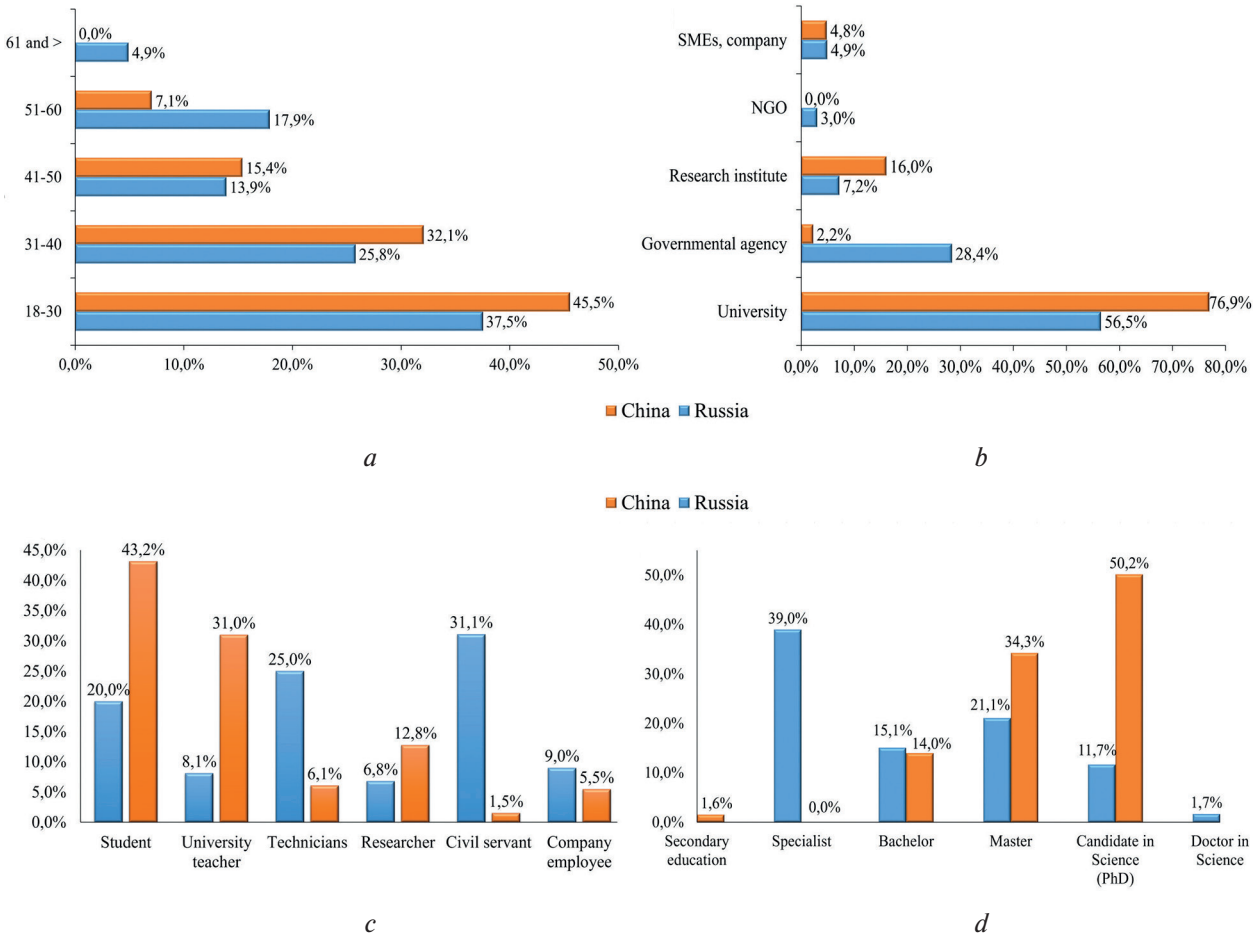


Fig. 2. Description of the survey respondents in terms of:
a — age; *b* — affiliation; c — position; *d* — educational background

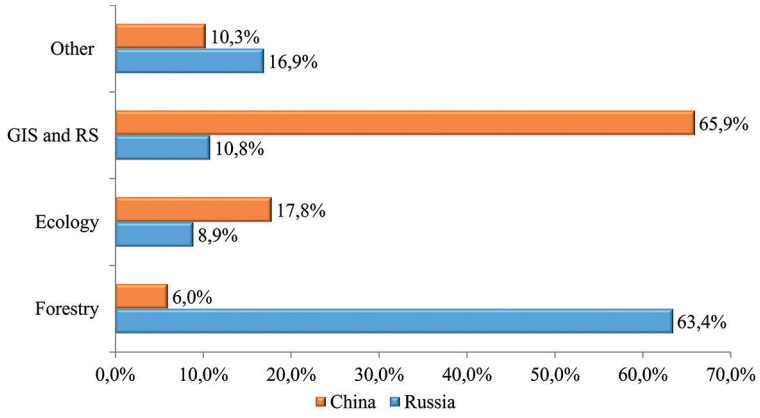
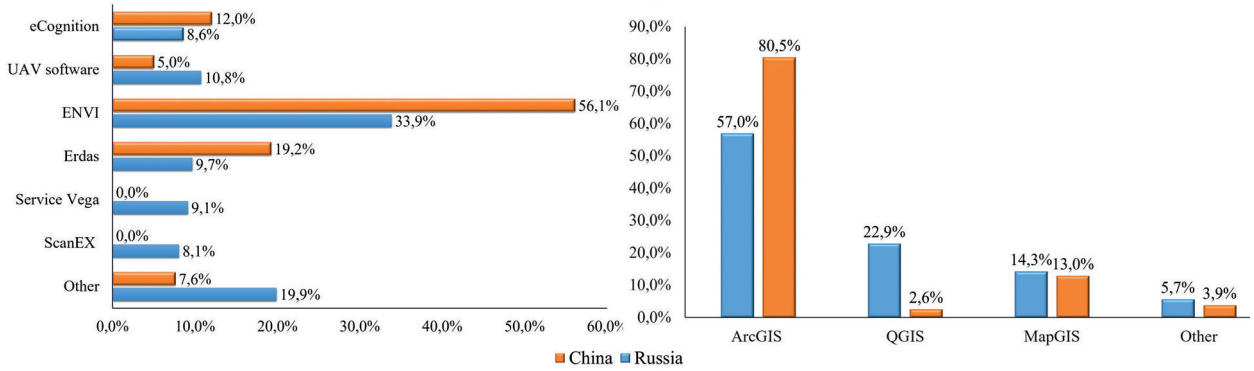


Fig. 3. Description of the survey respondents in terms of occupation (field of activity)

Most of the respondents in Russia (63.3 %) identify their field of activity as related to forestry, while in China only 6.0 % work in this field (*fig. 3*). On the other hand, most of the people in China (65.9 %) and only 10.8 % in Russia are directly involved in the field of GIS&RS. Such results can be explained by the fact that the SUFOGIS consortium members in Russia (universities) are mainly

engaged in the field of forestry, while in China they mostly focus on environmental studies. Therefore, the network of respondents consisted from the corresponding organizations from the partner countries, which led to such distribution in the survey results. In addition, these figures show a higher degree of GIS&RS use among the main stakeholders in China than in Russia.

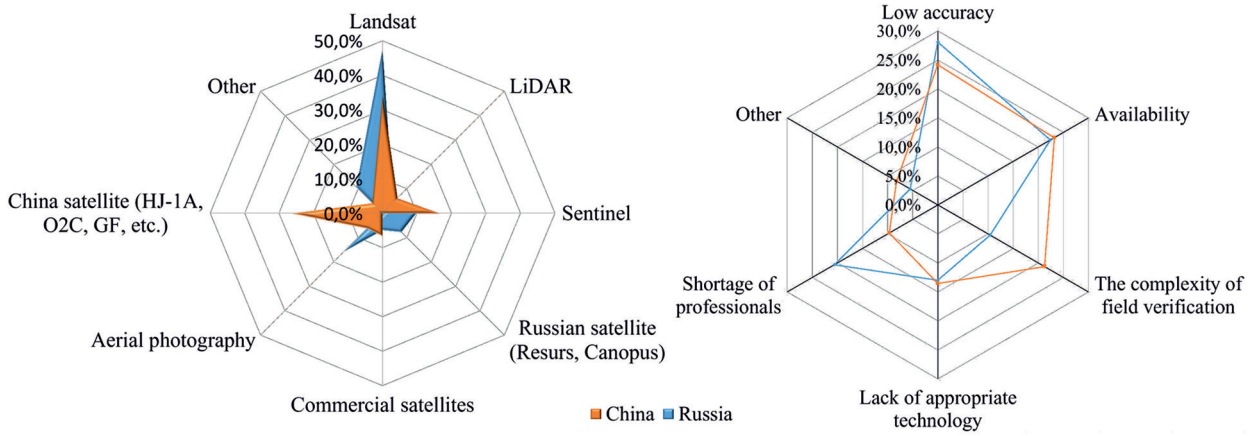
The Russian and Chinese respondents were asked to specify the software used for processing the GIS&RS data. The analysis shows that the majority of respondents use ENVI software (51.6 % in China and 33.9 % in Russia) when working with remote sensing data (*fig. 4a*). The second most popular software is Erdas Imagine (19.2 % in China and 9.7 % in Russia). The share of other RS software among the respondents is also quite significant (19.9 % in Russia and 7.6 % in China). It should also be noted that Russian respondents also use national software for processing RS images, such as Service Vega (9.1 %) and ScanEX (8.1 %).



a *b*

Fig. 4. The most used software: *a* — for processing RS data; *b* — GIS

Analysis of GIS applications used shows the following results: the most popular is ArcGIS (80.5 % in China and 57 % in Russia); QGIS is more frequenlty used in Russia (22.9 %) than in China (2.6 %); 5.7 % of Russian and 3.9 % of Chinese use other software GIS (*fig. 4b*).



a *b*

Fig. 5. Respondents answers regarding: *a* — satellite data used; *b* — deficiencies in using RS

According to the survey results, most of the respondents use Landsat satellite data (USGS) (43.7 % in Russia and 34.3 % in China) and the second position belongs to Sentinel (ESA) (16.5 % in Russia and 9.7 % in China) (*fig. 5a*). Chinese respondents (26.1 %) also widely use national satellite data (HJ-1A, O2C, GF), while Russian respondents (7.7 %) also use satellite data (Resurs, Canopus)

of Roskosmos (Russian Federal Space Agency). Low altitude digital aerial photography, lidar, commercial satellites (World View, GeoEYE, ALOS, SPOT, etc.) and others are used to a lesser extent. The extensive use of Landsat and Sentinel satellite data can be explained by its availability and free access.

28.1 % of respondents in Russia and 24.2 % in China consider the low classification accuracy and 20.6 %/9.7 % lack of professionals to be a significant drawback of RS in forestry/environmental monitoring, while 22.4 %/23.2 % regard the issue of accessibility to satellite images to be problematic (*fig. 5b*). Lack of appropriate technology (13 %/13.5 %) and complexity of field verification (10.4 %/21.3 %) also are indicated by the respondents as the drawbacks of insufficient use of GIS&RS in the field of forestry and ecology in Russia.

One of the survey's open questions was "What kind of GIS training would you like to have?" The results were as follows: 28.9 %/25 % (Russia/China) of respondents expressed their willingness to be trained in the basics of cartography; 26.7 %/22.5 % — in data collection and management: formatting, editing, topology, data conversion and GIS; 8.3 %/12.5 % — in map design and visualization: symbolization, analysis of attribute information, clipping and segmentation, atlas, web mapping; 21.5 %/20.0 % — in spatial analysis: environmental sensitivity analysis, land suitability analysis, hydrological analysis and other three-dimensional analysis: DEM (digital elevation model) data acquisition, surface visualization, three-dimensional visualization, three-dimensional mapping, terrain analysis, landscape analysis (*fig. 6*).

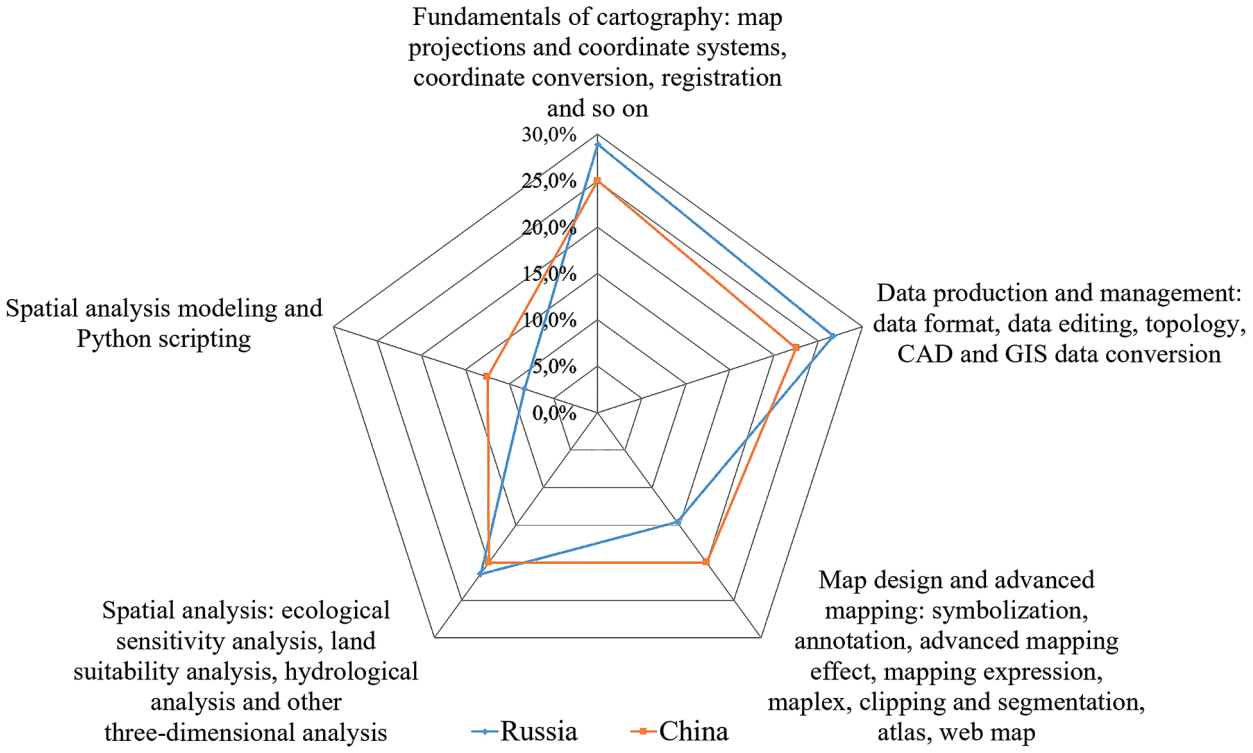
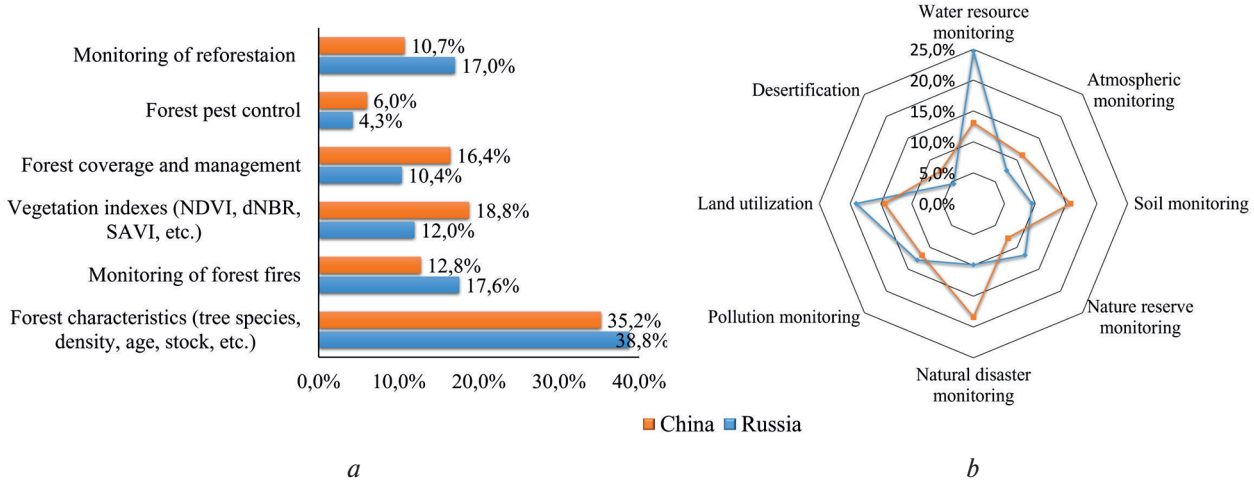


Fig. 6. Distribution of target groups' interest in the GIS fields of training

There are 38.8 %/35.2 % (Russia/China) of respondents who are willing to participate in the RS/GIS professional training concerning the detecting of forest dendrometry characteristics (tree species, density, age, stock, etc.), followed by 17.6 %/12.8 % interested in monitoring of forest fires (*fig. 7a*, see p. 16). Considerable group of respondents (12 %/18.8 %) has great interest in the combination of GIS&RS for studying (research) of vegetation indexes (NDVI, dNBR, SAVI, etc.) and monitoring of forest cover and management in forest sector (10.4 %/16.4%).

Next groups show their interest in GIS&RS applications in ecological issues, which accounts for 51.03 % of respondents in both countries (*fig. 7b*). Professional training in the field of water resource

monitoring with the use of GIS&RS software is high in Russia (24.7%), while Chinese respondents are more willing to be trained in the field of natural disaster (18.4 %) and soils (15.7 %) monitoring. Land utilization (19.0 %/14.4 %) and pollution monitoring (12.9 %/11.8 %) are of high importance among the respondents in Russia and China. Desertification issues are of more interest in China (7.5 %), while nature reserves monitoring is of higher importance in Russia (11.8 %).



a *b*

Fig. 7. Distribution of target groups' interest in the fields of training:
a — forestry; *b* — environment and nature management

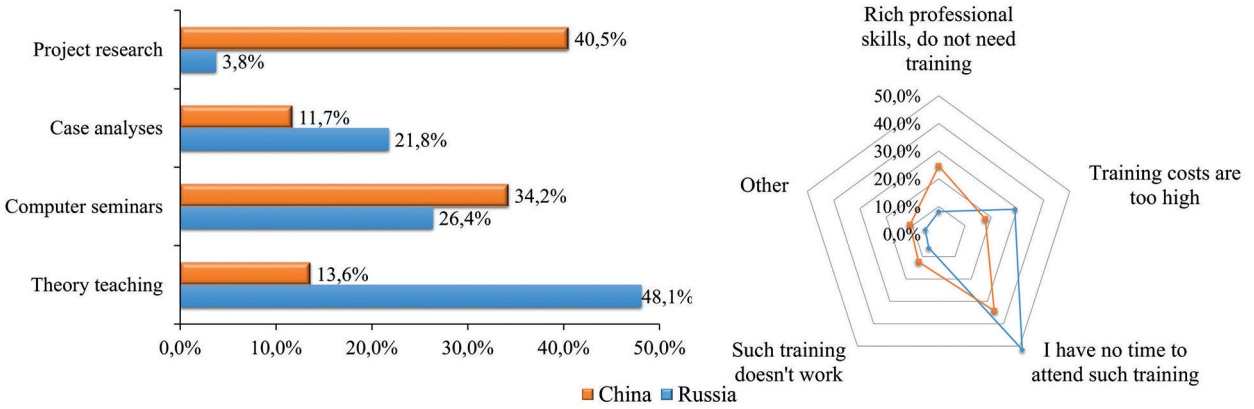


Fig. 8. Distribution of target groups' feedback on: *a* — training model; *b* — reason no to attend

The next portion of the survey questions is about the training models and the reasons of those people who are not willing to participate in the training (*fig. 8*). Overall, most of respondents show interest in professional training. Russian participants of the survey choose to have more theory-oriented teaching model (48.1 %), while Chinese participants are interested in project research model (40.5 %) (*fig. 8a*). Both groups indicate interest in computer seminars (26.4 %/34.2 %) and practical work abundant in case analysis (21.8 %/11.7 %).

The survey results show that 51.5 % respondents in Russia and 34.2 % in China think that they have no time attending workshops (*fig. 8b*). The next reason not to attend the trainings is cost (29.0 %/17.8 %) and high professional skills of the respondents (8.2 % in Russia and 24.7 % in China).

The analysis also reveals that 226 respondents in Russia consider low funding of research to be the main reason for weak cooperation between universities and enterprises. According to 219 people, the reason is the lack of highly qualified specialists working in the most advanced areas and the dominance of foreign satellite data and programs. 208 people believe that teaching is prioritized over research at universities, and 206 respondents blame the lack of innovative entrepreneurship.

Discussion and conclusions

This paper is part of the SUFOGIS project, which intends to make a significant contribution towards the use of GIS&RS in sustainable forestry and ecology in Russia and China. The survey questionnaire design and analysis took into account the needs and points of view of the different target groups (users) in both countries. The respondents were from different backgrounds, held different job positions and resided in different households, which meant to ensure the representation of the survey and provided a comprehensive opinion of various population groups on the use of GIS&RS for sustainable forest management and environmental monitoring. The survey with a high response rate of 819 participants draw a detailed picture of GIS&RS practices, used software and remote sensing data, interests in trainings and many other issues in Russia and China.

A particular challenge of this survey is the comparisons of GIS&RS use between the two countries, taken into account vast fast area of forest resources and emerging economies. The results reveal evidence of increased use and awareness of importance of the GIS&RS in both countries as worth the money powerful tool for data management, research and monitoring in the forest sector and ecology. The two most commonly used software packages in both countries are ArcGIS and QGIS, while for the image processing the respondents choose ENVI, Erdas and eCognition software. On the other hand, other, including local, products for image processing are also popular, especially among Russian participants of the survey. The answers also reflect the increasing popularity of open source packages and satellite imagers (Landsat and Sentinel).

Despite continuing reforming of the forest sectors in Russia and China over the past decades, there have been significant increases in the use of these technologies for wide range of policy related and practical application tasks beyond basic mapping. These include the use of GIS&RS in applications such as estimation and analysis of dendrometry parameters of forest stands, vegetation indexes, monitoring of forest fires, forest cover and reforestation issues. Another group of participants (ecologists) is eager to be trained in the field of monitoring of water resources, land utilisation, natural disaster, and atmospheric pollution, which could enhance their career prospects.

Although a large share of the SUFOGIS respondents are from academia, survey findings confirm high demand of all respondents in trainings related to the different aspects of the GIS&RS applications. This is probably due to the high provision of opportunities of the consortium members to develop and disseminate the unique competences in the field with the right mix of academic preparation and training (internships). Another remarkable finding of the survey is that more than 20 % of the respondents in both countries are interested in spatial analysis techniques for GIS&RS applications in forestry and ecology, although this is the most difficult part of the studies. In a sense, the principal lack of knowledge in the spatial analysis of Russian and Chinese graduates simply could be because there is not enough focus on these issues in university curriculums related to GIS&RS.

Although such findings may seem unsurprising for the professional community, they highlight important issues concerning the present situation with the GIS&RS training programs and how they are adapted to the practical skills of graduates in view of employment. Hence this survey results may be useful for a diverse group of stakeholders in Russia and China. The SUFOGIS survey has identified a number of ways in which current GIS&RS teaching/training could be further strengthened and enhanced during the project implementation. There is a clear need for the lessons learnt from applying GIS&RS tools in a wide range of areas to be more widely disseminated in order to encourage their use in both countries. The project team is aware of the need to extend the results presented here for the use on the national level in Russia and China to assess the actual context in which GIS&RS is being used in forestry and ecology.

The study also suggests further use of the SUFOGIS survey results for analytical (operational) work among the decision making organizations (ministries, state departments) in the respective fields of studies in both countries. Furthermore, the obtained data provide a valuable starting point for future research of the GIS&RS uses for the implementation of sustainable forest management and ecology.

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Обзор использования ГИС и дистанционного зондирования для устойчивого лесоводства и экологии в России и Китае

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Во всём мире наблюдается рост использования в различных областях мощных геопространственных технологий, таких как географические информационные системы (GIS) и дистанционное зондирование Земли (RS) GIS&RS. Проект Erasmus+ SUFOGIS, который выполняется в тесном сотрудничестве между партнёрами из России, Китая и ЕС, предполагает инновационный подход в этой области, основанный на «знаниях, компетенциях и навыках». Статья посвящена сравнительному анализу результатов двух отдельных национальных исследований, проведённых партнёрами SUFOGIS в России и Китае, по внедрению и использованию GIS&RS в области лесного хозяйства и экологии. На основе анализа анкет и с учётом типа организации, в которой работает респондент, были выделены две основные категории для опроса: академические учреждения (университеты, колледжи и исследовательские институты) и компании (государственные и частные). Результаты анализа явно демонстрируют широкое использование GIS&RS в странах, не входящих в Европейский союз, и относительно высокий уровень компетентности респондентов. Тем не менее также было выявлено, что ещё есть большие возможности для совершенствования использования GIS&RS в обеих вышеупомянутых странах. Такими примерами могут служить изучение возможности их интеграции в большее количество направлений деятельности в области лесоводства и экологии, а также обучение персонала по продвинутым и специализированным направлениям.

Ключевые слова: ГИС, дистанционное зондирование, лесное хозяйство, анкетирование, окружающая среда, Erasmus+, Россия, Китай

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