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Limited GIS skills hamper spatial planning for green infrastructures in Sweden

Foreword

This article was written in 2013 and was intended to be submitted to and subsequently published in a scientific journal. As the lead author passed away during the publication process, this did not happen, and the article was never published. We do, however, think that the results may still be of value for the education community being interested in geography, GIS and spatial planning. Thanks to the good will of Geografilärarnas Riksförening and its journal Geografiska Notiser, a window of opportunity aroused to disseminate its content to a broader audience, something we are very thankful for. The content of the article includes the original manuscript in its entirety, as well as a new section presenting case studies of how GIS can support spatial planning for green infrastructures.

Abstract

The term green infrastructure captures the need to conserve biodiversity and to sustain landscapes' different ecosystem services. Maintaining green infrastructures through protected areas, management and landscape restoration requires knowledge in geography, spatial data about biophysical, anthropogenic and immaterial values, spatial comprehensive planning, and thus geographical information systems (GIS). To understand land use planning practices and planning education regarding GIS in Sweden we interviewed 43 planners and reviewed 20 planning education programmes. All planners used GIS to look at data but did not carry out spatial analyses of land covers. BSc programmes included more GIS than MSc programmes but very few taught analyses for spatial planning. As key spatial planning actors, municipalities' barriers and bridges for improved GIS use for collaborative learning about green infrastructures are discussed. A concluding section presents examples of how GIS can support spatial planning for green infrastructures.

Key words: GIS education, green infrastructures, municipal planning, spatial analyses, geodata

Introduction

Maintaining ecological, economic, social, and cultural dimensions of landscapes as social-ecological systems is a contemporary challenge (e.g., Angelstam, Grodzynskyi, *et al.*, 2013; Axelsson *et al.*, 2013). Place-based adaption of planning theory to new demands in different contexts is increasingly important (Antrop *et al.*, 2013; Friedmann, 2008). This is thus reflected in multiple policy areas (e.g., Council of Europe, 2000, 2006; European Commission, 2000; European Council, 2005, 2011), and applies to all land covers' use and non-use values (Richnau *et al.*, 2013, Axelsson *et al.*, 2013). Regarding

forests, Swedish national policies (Government Bill 2007/08:108; SOU 2013: 43) stress the need to enhance the outcomes in terms of increased use of renewable raw material, conservation of biological diversity as well as social and cultural values as foundations for rural development. The European Council (2013) aims at fostering competitiveness of agriculture, ensuring sustainable management of natural resources, and achieving a balanced territorial development of rural economies and communities. Wetlands provide many ecosystem services supporting water security and are a natural infrastructure that can help meet a range of policy objectives. Wetland loss can lead to significant losses of human well-being, and has negative economic impacts on communities, countries and business (Russi *et al.*, 2013). Concerning water, the EU Water Framework Directive (European Commission, 2000) promotes sustainable water use and improving the quality of "*the network of natural and semi-natural areas, features and green spaces in rural and urban, and terrestrial, freshwater, coastal and marine areas, which together enhance ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services*".

Ecosystem services are the benefits people need or desire from ecosystems (Millenium Ecosystem Assessment [MEA], 2005), and include provisioning services, regulating services, cultural services, and habitat or supporting services. Implementation of policies about green infrastructure involves challenges for spatial planning and co-ordinated initiatives across

territories to protect, manage and restore habitat and connectivity for biodiversity (i.e., the composition, structure and function of ecosystems *sensu* Noss, 1990), as a foundation for delivering multiple ecosystem services (MEA, 2005). This requires consideration of scales beyond the local, i.e., also landscape and regional scales (Andersson *et al.* 2013), and that available knowledge about the states and trends of different land covers and their functionality as green infrastructures are available (Andersson *et al.*, 2013; SOU 2005:94). This stresses the need for integrated spatial planning across entire territories (UNECE, 2008). To identify potential synergies or conflicting interests among landowners, land use interests, municipalities and other actors, collaboration at landscape and regional levels are necessary (Cowie *et al.*, 2007). Sustainable development as a social process and spatial planning for sustainability thus requires a comprehensive approach with integration of a wide range of different types of land cover information and the sectors using them (Elbakidze & Angelstam, 2009). To implement contemporary policies aiming at sustainable landscapes there is a need to measure and develop planning and governance approaches that provide decision-makers with knowledge about the state and trends of indicators for different sustainability criteria in relation to agreed norms as support to their decisions (Angelstam, Elbakidze, *et al.*, 2013; Espon, 2013). To guide planning processes within and across many land holdings it is therefore important to collect, analyse and present data for all sustainability dimensions (Angelstam, Grodzynskyi, *et al.*, 2013; Mozgeris 2009).

Geographic information systems (GIS) are tools that provide techniques that can support spatial planning and multi-level governance for three main reasons (Sieber, 2006). First, most information used in policy-making contains a spatial component. Second, extending the use of spatial information to all relevant actors and stakeholders in a territory may lead to better policy implementation through better communication and collaboration. Third, land use and land cover data, statistics and policy-related information can often be analysed and visualised spatially. The resulting output can then be communicated among different stakeholders as a base for governance and management at multiple levels (Balram *et al.*, 2004). GIS thus includes tools for data analysis, spatial modelling and visualisation, which provide actors and stakeholders of different backgrounds in planning processes with a common language for communication (Brandt & Jiang, 2004). Furthermore, GIS can function as a decision support tool for a wide number of applications (Marinoni *et al.*, 2009). Therefore, it has the potential to be used as a tool for integration of different sustainability dimensions (Graymore *et al.*, 2009). GIS can be used to combine measurable data with text, using fuzzy logic, and can thus even function as a sensitivity analysis tool, also in a spatial context (Kordi & Brandt, 2012).

Sweden is a latitudinally extended country with many different types of landscapes, ranging from temperate to boreal and mountain ecoregions. Traditional sectors based on natural resources such as forestry, agriculture and mining are active across most of Sweden. Economically, ho-

wever, their roles have declined over recent decades and now make up 2% of GDP (SCB, 2012) and 26% of the net export value (SCB, 2013). On the other hand, service sectors such as tourism and recreation are increasing (Tillväxtverket, 2013). Additionally, nonuse values such as biodiversity and cultural landscape are highlighted in discussions about what constitutes long-term sustainable land use (SOU 2013:43). Altogether, this illustrates the need for spatial planning to accommodate diverse interests. Sweden is also actively participating in global negotiations on sustainable development and conservation (Stockholm+40, 2012). As a member of the EU, EU policies on green infrastructure are adopted (Council of Europe, 2000; European Commission, 2010).

Regional county administrations have the responsibility for conservation in general and work with developing a network of formally protected areas, while the Swedish Forest Agency is responsible for conservation of biodiversity in managed forests. At the ground level, however, municipalities are the only actor that can produce plans that are not only of an advisory or strategic character (PBL 2010). Historically these plans handled built areas and built-up infrastructure, but the trend is that municipalities should take responsibility for also planning of green infrastructure across the municipal territory (Boverket, 2012). Thus, Sweden is an interesting country to study how planning for green infrastructures is carried out. Sweden is also a country with much evidence-based knowledge about what constitutes a functional green infrastructure (e.g., Angelstam, Roberge, *et al.*, 2013).

The aim of this study is to investigate the current role of GIS as a tool in the processes of knowledge production and learning to meet the new demands on spatial planning towards functional green infrastructures. We address two research questions. Are the planners competent and skilled to use GIS for planning about green infrastructures? Are the Swedish universities offering appropriate study programmes and courses? First, we present results from interviews with practicing spatial planners. Second, we review the spatial planning education in Sweden, with emphasis on landscape or physical planning to manage green infrastructures. A concluding section presents a suite of case studies of how GIS can support spatial planning for green infrastructures.

Methods
Interviews with planners

Sweden's main green infrastructures are different forest environments, such as on different site types and with different tree species structure, and different tree and stand age structures (e.g., Angelstam *et al*., 2011). To understand how well planners in the field of green infrastructure planning across landscapes outside settlements cope with the increased demands of using tools for spatial analysis, in-depth interviews were carried out with planners of forestry and conservation. Interviews were made in south (Helgeå river catchment; 56 N, 12 E), south-central (Bergslagen and Mälardalen; 13 N, 59 E) and north Sweden (Ångermanälven catchment; 13 N, 64 E), respectively. In total we interviewed 43 persons. First, we identified all categories of orga-

nisations involved in planning of green infrastructures. Then we interviewed planners from all categories. The interviewees represented the following categories: (1) private and state-owned forest companies (2) organisations and businesses making forest management plans and selling their services (e.g., forest owner associations, forest industries and forest consultancy bureaus); (3) municipalities; (4) forest agency districts; (5) county administrations; (6) other actors proposed by groups 1–5. The questions focused on: (1) what policies guided planners, (2) what biodiversity is, i.e. composition, structure and function of ecosystems (Noss, 1990), (3) what land covers were planned, (4) the spatial extent of plans, (5) the use of GIS, and (6) need for more knowledge (see Appendix).

Survey of planning education with respect to GIS

University education for GIS engineers and scientists has been available in Sweden since the beginning of the 1990s. In 2006, 23 universities offered about 150 courses in GIS at different levels, and six universities provided entire GIS-programmes (Brandt & Arnberg 2007; Brandt *et al*., 2006). Although the number of universities providing complete programmes has decreased to four since then, many GIS-courses function as toolkit courses for other subjects. As a result, more and more people with GIS skills are available. Using Swedish universities' web sites an inventory of expected learning outcomes in the curricula for spatial planning programmes was made to understand the extent to which students are taught about GIS analyses, and thus are

able to meet the new demands on spatial planning for green infrastructures. In Sweden, many educational programmes exist that claim to produce planning professionals. We focused on programmes in spatial planning toward landscape and physical planning to see to what extent GIS is used. Both the contents and the numbers of mandatory or recommended courses of the programmes differed among the universities. Some had the complete programme determined from the start of the education, while some only provided a frame where the students are allowed to take more or less any courses they would like as long as they fulfil the requirement of a minimum number of credits within the subject. The present survey has, therefore, only looked at the mandatory and recommended courses in the programme curricula, leaving out the possibility that one or a few students may have the opportunity to take more GIS than actually is described in those curricula. The analysis focused on (1) differences between BSc and MSc programmes regarding the amount of GIS content, and (2) the extent to which GIS education had an analytic component.

Results
Planning practice concerning green infrastructures

In our study the interviewees' average time with the current work was 9 years and their average age was 45 years. Their education background was mostly in forestry and biology. Four of the 43 interviewees had a PhD degree. The most common regulations or policies that guided planners' work with green infrastructure were the Swedish Environmental Code, the Forest Stewardship Council, the Programme for the Endorsement of Forest Certification, the Forestry Act, comprehensive municipal plans, and the Swedish environmental objectives, but also the organisations' and businesses' own local policies and guidelines. No one mentioned any of the EU or Pan-European policies about landscape and green infrastructure such as Council of Europe (2000), MEA (2005) and European Commission (2010) as guides to their work.

When asked about what biodiversity is, all mentioned species and their habitats. A few mentioned processes at the ecosystem level. One third of the interviewees did not use any specific species or knowledge about their habitat demands. The other two thirds used the presence of red-listed species and indicator species. Despite this they did not use evidence- based knowledge about these species' habitat needs as a base for assessing green infrastructure functionality.

The planning focused on different habitats in different regions. In south Sweden the focal habitats were broadleaf forest, pasture and water. In south-central Sweden a large variation of environments including old deciduous, old pine forest, oaks in the agricultural landscape, wetland, water, meadow, and urban forest were considered. In north Sweden old forest, water, mire, mountain forest and urban forest were mentioned. The size of the area planned for varied much depending on the organisation, from 3 ha on private land up to 10,000 ha on forest company owned land, and to entire municipalities. Interviewees mentioned the need to plan for entire landscapes, taking into account all land co-

ver categories across spatial scales. Additionally, they meant that landowners need more knowledge, and that the dialogue with landowners needs to be improved.

Almost all interviewees used GIS, but only as a viewer to look at the data. About half of them used field computers and GPS. Four made simple overlay analyses, but none did any spatial modelling in larger landscapes. Some of the organisations had a GIS-educated specialist. GIS data used included databases about protected areas and key biotopes. The informants mostly got their data on species and habitats location from The County Administrative Boards, the Swedish Species Information Centre and the Swedish Forest Agency. Many also did their own inventories, such as woodland key biotopes. Four of the interviewees had regular contacts with researchers or read scientific papers.

The majority of interviewees stated that they need and have opportunity to vocational education, but many argued they have no time, and that the organisations have no money for needed training. Most of the training the planners participated in was very short, in general one- or two-day courses with a focus on biology only. None of the mentioned courses included spatial analysis with GIS.

Survey of planning education with respect to GIS

The results from the planning curriculum survey revealed two main findings. First, among the surveyed BSc level programmes (three years long, i.e. 180 credits in the European credit transfer system, ECTS) all had specific courses in GIS because at least basic GIS skills are considered to be essential for professional spatial planners (Table 1). With respect to more advanced knowledge of GIS, including modelling and analysis, only two of the nine BSc programmes provided such knowledge. For MSc programmes on the other hand, only four out of eleven included GIS in their standard curricula (Table 2). Second, the topics treated in most GIS courses included generic skills like GIS formats, overlaying, and map production. Besides the obvious relation to planning issues, which most programmes adhered to, some other specializations, was noted among the three universities where GIS plays a central role. The University of Gävle focused much on cartography and 3D-visualization and was also the only one where spatial multi-criteria analysis was mentioned in the course syllabus, while the University of Umeå had a strong focus on statistics, and SLU in Alnarp focused on landscape analysis, such as sight analysis and analysis prior to wind power establishments and visualization.

Discussion
Planners do not use GIS to its full potential

All informants and their organisations used GIS to look at different data or used GIS together with GPS as important parts of their fieldwork. However, they did not make any spatial analyses linked to green infrastructures of representative land covers. Nevertheless, planners argued that they have all data they need for the planning, including both nation-wide datasets and local inventories. When asked

Table 1. Spatial planning programmes in Sweden on basic (BSc) level. Swedish programme names within square brackets.

University	Programme	Level	ECTS total	ECTS GIS[1]	Relevant courses (ECTS)
Gävle	Study programme in spatial planning [Samhällsplanerarprogrammet]	BSc	180	45	• Geographical information technology (7.5) • GIT in land management (7.5) • Remote sensing and GIS analysis in land management (7.5) • Cartography (7.5) • CAD for land management (7.5) • Geovisualisation in built environment (7.5) (CAD & GIS are used)
Umeå	Spatial planning [Samhällsplanerarprogrammet]	BSc	180	Ca 35	• Methods in human geography, (15) • GIS and spatial analysis (15) • GIS, mobility and systems (15)
SLU in Skinnskatteberg (Optional GIS -elated courses given at Umeå)	School for forest management [Skogsmästarprogrammet]. GIS is integrated as a tool in forest planning courses	BSc	180	22.5	• Laser scanning and digital photogrammetry in the forestry (7.5) • Forest remote sensing (7.5) • Geographical information technology II (7.5)
Karlstad	Social planning programme [Samhällsplanerarprogrammet]	BSc	180	20	• In Methods of spatial and social planning (7.5) GIS is touched upon • Introduction to GIS, as a tool in social planning (7.5) • GIS, social planning and project work (12.5)
Uppsala	Urban and regional planning [Samhällsplaneringsprogram]	BSc	180	15+	• Geographical information systems (GIS) in planning (15) • Method and analysis (7.5) (GIS is treated)
Lund	Urban and regional planning [Samhällsplanering – urban och regional utveckling]	BSc	180	15	• GIS in urban and regional planning: project work (7.5) • GIS in regional planning (7.5)
Stockholm	Urban and regional planning [Samhällsplanerarprogrammet]	BSc	180	15	• "Geographical data" (15)
Malmö	"Urban development and planning" [Stadsbyggnad, stadsutveckling och planering]	BSc	180	10+	• "GIS statistics in comprehensive planning" (10) • "Digital tools I" (7.5) (CAD is treated)
Blekinge Institute of Technology	Spatial planning [Fysisk planering]	BSc	180	8	• Geographic information systems (8)

[1] GIS and closely related areas such as cartography, remote sensing, etc.

about their need for education, they mentioned forestry and biology, but no one mention need for education in GIS analyses or landscape modelling. These results are consistent with previous studies from Sweden. The Swedish Development Council for Land Information, ULI, has carried out surveys about the use of GIS and geographic information in Sweden since 1990 with a few years' interval. In the survey from year 2000 (Andersson, 2001), the number of people who use GIS

Table 2. Spatial planning programmes in Sweden on advanced (MSc) level (spring 2013).

University	Programme	Level	ECTS total	ECTS GIS[1]	Relevant courses (ECTS)
Umeå	Spatial planning and development	MSc	60 or 120	Ca 20 or ca 35	• Human geography, planning and GIS (15) • Advanced spatial analysis (15) • Methods and modelling (15)
SLU in Alnarp	Landscape architecture	BSc-MSc	300	Ca 35	• Advanced digital landscape analysis with GIS (15) • Digital landscape visualisation (15) (CAD is used)
SLU in Umeå	MSc in forestry	MSc	300	22	• Geographic information technology I (7) • Geographic information technology II (7,5) • Forest remote sensing (7.5)
SLU in Ultuna	Landscape architect	BSc-MSc	300	10+	• Geographical information systems and geographic analysis (10) • Design through practice and management (15) (GIS is used)
Blekinge Institute of Technology	MSc programme in spatial planning [Masterprogram i fysisk planering]	MSc	120	0	none
Blekinge Institute of Technology	Master programme in European spatial planning and regional development [Magister/Masterprogram i europeisk planering och regional utveckling]	MSc	60 or 120	0	none
Karlstad	Master programme region building [Magister-/masterprogram Regionalt samhällsbyggande]	MSc	60 or 120	0	none
Royal Inst. of Technology (KTH)	Sustainable urban planning and design	MSc	120	0	none
Stockholm	Environmental management and physical planning [Miljövård och fysisk planering]	MSc	120	0	none
Stockholm	Urban and regional planning [Samhällsplanering]	MSc	120	0	none
Uppsala	Master programme in social sciences (spec. spatial planning]) [Masterprogram i samhällsvetenskap – inr. samhällsplanering]	MSc	60 or 120	0	none

[1] GIS and closely related areas such as cartography, remote sensing, etc.

in their daily work was 14,732, an increase by 39% from 1997 to 2000. The most common GIS applications used were for municipal physical planning of land use and general mapping. The largest increase was found in the use of simple systems such as data viewers. In 2005 there was a clear concentration of organisations using GIS in large urban regions (Ottosson & Samuelsson, 2005). The largest application areas for geographic information (more than 196 organisations) were in municipal physical planning of land use and general map production. Ad-

ditionally, 50–150 organisations used geographic information for forestry, education, sports, tourism, geology, health and social care, IT services, rescue, and agriculture planning. The informants stated in both ULI surveys that the largest obstacles for a continuous development are the cost for data and GIS systems. The lack of the staff's GIS skills, and limited interest and understanding of the usefulness of GIS within the organisation were also regarded as major problems. The most important elements for success were skills and education of staff to use GIS. Another important advantage of GIS was that organisations were considered to be more effective in their work, and that the entire organization became more efficient. In recent years, the use of geographic information has been broadened (ULI, 2008), and only one percent of the organisations in that survey did not use GIS. However, it is the simple use of GIS that has increased the most, such as data viewing, whereas more advanced analyses are still uncommon outside academia. A total of 90% of the organisations in ULI (2008) see a need for greater expertise on GIS.

From the survey of curricula, it appears that in general that BSc programmes take a stronger responsibility for including GIS than do the MSc's programmes. For the BSc level this might be due to strong demands from the municipalities and companies that the new hired staff must master basic GIS skills. For the MSc level, on the other hand, the relative lack of GIS might be due to stronger demands of the higher education in Sweden to be more theoretically oriented, rather than oriented towards learning planning tools.

This is evident from the text in Annex 2 of the Swedish Higher Education Ordinance (SFS 2006:1053) regarding a BSc degree compared with a MSc degree. Regarding learning outcomes of knowledge and understanding, a BSc degree requires that the student shall demonstrate "*awareness* of current research issues". For the same goal an MSc's degree requires that the student shall demonstrate "*insight* into current research and development work" in the main field of study.

Edwards and Bates (2011) found that the lack of GIS and spatial analysis courses, in some of their surveyed MSc's programmes in the United States and Canada, may be due to that the institutions also have PhD programmes in planning, and that they therefore are more academically oriented. However, the lack of courses containing GIS as a tool that actually is capable of handling and analysing complex spatial data is somewhat surprising as the Swedish Higher education act (SFS 1992:1434) text for MSc's degree states that the student also shall "demonstrate the ability to integrate knowledge and analyse, assess and deal with phenomena, issues and situations", albeit not explicitly demanded to be in the form of using GIS. Either the universities rely on that students do already have GIS skills from their BSc degrees, or it may be that the universities simply do not consider GIS skills to be necessary at the MSc level. Internationally, GIS has for a relatively long time been recognised as a valuable tool in planning education. For example Friedmann (1996, p. 99) pointed out that "Students should acquire not only a basic understanding of the significance of space and spatial theo-

ries at all relevant scales about how space interacts with individual and social behaviour, but also acquire the skills of geographical representation through computerized geographical information systems". That was expressed at the time when most social sciences, except geography, where taught without considering the spatial dimension (Friedman, 1996). A follow up on that study was the one by Edwards and Bates (2011) who found that only five out of thirty planning schools with MSc programmes in the United States and Canada included required courses in GIS or spatial analysis.

There is, however, a good potential to increase the use of GIS in planning. Studies show that the development of GIS to become a general tool for planning is only at the initial step (Blicharska *et al*., 2011; Göçmen & Ventura, 2010; Ottosson & Samuelsson, 2005; ULI 2008). Hence, different organisations state that they need greater expertise to use GIS. But if education programmes in planning train their students to be GIS users only, developments in GIS and the planning profession will evolve independently (Drummond & French, 2008). As many educational programmes focus on either GIS or on planning, despite that GIS now has been established as a tool in many land use sectors, there is now a need to fully integrate GIS in planning education. This integration should be possibly to achieve without impairing the education's theoretical content. Below, to summarise the findings of this and other studies, we present a SWOT analysis (Pershing, 2006) of the use of GIS in Swedish land use planning.

The use of GIS in Swedish land use planning – a SWOT analysis

Strengths included that much digital spatial data that can be used to describe different dimensions of sustainability is indeed available. In Sweden, there are several nation-wide land cover databases suitable for planning of landscapes available for free online. Another strength is that the different kinds of spatial data described above can be combined using GIS to produce new otherwise unavailable information useful for spatial planning of green infrastructures. Moreover, there are many GIS tools for spatial planning, both to view the data and for more advanced modelling (e.g., Karl, 2010). GIS is also a good platform to communicate spatial information among planners, decision makers and the society (Mozgeris 2009; Sandström *et al*., 2003).

One of the main *weaknesses* is that, with a few exceptions, planners do not have theoretical knowledge or GIS skills to do advanced GIS analyses of green infrastructure functionality. Despite the advances in the development of GIS, practical application in assessment and planning of functional green infrastructures is limited due to poorly developed collaboration and planning, for example among different landowner categories (Andersson *et al*., 2013; Angelstam *et al*., 2011; Axelsson *et al*., 2011; Blicharska *et al*., 2011). Therefore, the efficiency of protected and set-aside areas for conservation in forests, agricultural landscapes and urban environments is too poor (e.g., Angelstam *et al*., 2011). For example, on average only 15% of forest habitats form funning

ctional habitat networks (see Angelstam *et al*., 2011). This clearly shows the potential in improved planning of green infrastructures.

A prerequisite for improved planning is improved education and vocational training. Additionally, information from biological surveys has a limited accessibility (SOU 2005:94). Another important issue is that in many municipalities, GIS-experts and land use planners often are different persons (e.g., Reneland, 2000). In contrast, land use planning requires that different professional perspectives meet (e.g., Sandström *et al*., 2003). *Opportunities* for more use of GIS in spatial planning are abundant because techniques and appropriate software are continuously being developed, and the amount of open source GIS applications and data that are available is increasing (Steiniger & Bocher, 2008). For example, with the aim to support more use of spatial data and GIS in planning, the EU INSPIRE directive encourages gathering data at one place to make spatial data more interoperable and easier to access (European Commission, 2007). Also a Swedish national forest database is planned to be developed and may allow deeper interagency cooperation as well as improved access for other stakeholders (Skogsstyrelsen, 2009). With the expansion of new GIS tools and better access to databases, the development of predictive distribution models about focal species for different green infrastructures is increasing (Elith *et al*., 2006). The use of GIS is also spreading to new sectors like healthcare, epidemiology and school management, and the number of professionals who use GIS is increasing (ULI, 2008).

One of the *threats* to GIS use in planning is the lack of skills among planners in using GIS. According to ULI (2008) 90% of organisations using GIS claim that they need higher skills in using GIS. Moreover, many planners may not have enough resources to do all that they want concerning green infrastructure planning for biodiversity conservation (Blicharska *et al*., 2011), and to enhance ecosystem services (MEA, 2005).

Summarising, the use of GIS in spatial planning has not reached the level that policy makers and scholars have envisioned (Merry *et al*., 2008). Moreover, planners are not aware of the full potential of GIS for planning purposes (Göçmen & Ventura, 2010). This reflects the situation that the knowledge about GIS in planning is insufficient, and that GIS is mainly used as a database or as a digital map tool (Wei *et al*., 2011). Training and understanding of GIS is the barrier to realize the potential for modelling or spatial analysis (Göçmen & Ventura 2010, ULI 2008). Finally, GIS-experts and planning staff often are different persons in different units of organisations, which might lead to poor integration of GIS and planning. In addition, planning is resource demanding due to different professional and other perspectives that are involved, which need to be integrated (Göçmen & Ventura 2010; Reneland, 2000). There is therefore reason to further develop the education of spatial planners, both in terms of the theory and practice related to the use of GIS. This includes operation of GIS software as well as modelling and spatial analysis, and the use of GIS to integrate different perspectives.

How to improve GIS skills for planning green infrastructures?

The need for spatial analyses at multiple scales to implement on the ground functional green infrastructure policies clearly stresses the necessity of more and advanced use of GIS in the planning processes. Thus, there is a need for improved GIS-use skills of the actors involved with planning in landscapes and regions, and for making planners aware of the possibilities with GIS as a general tool for collaboration among different planning sectors (Göçmen & Ventura 2010; ULI 2008). Education is also very important to increase awareness of the functional green infrastructures, and how they can benefit through adaptive management (Naumann *et al.*, 2011).

From which type of education should then the planners with GIS skills be taken? Based on the education programme survey it is evident that all planners holding a relatively recent BSc degree have got in touch with GIS during their studies, at least to some degree. Therefore all of them should be capable of performing simple GIS operations. However, if more complicated GIS tasks are required, such as analyses of functional connectivity of networks of high conservation value land cover patches, only a handful of the planning programmes are capable of providing those skills. Also, a somewhat unexpected situation may occur if the student apparently has an advanced planning degree, from a programme where no GIS courses are included, and the previous studies have been a BSc degree from a non-planning subject. Then their GIS skills are practically zero. An-

other source of personnel is programmes in GIS engineering or software development. Although these students are stronger in terms of GIS, they generally lack a thorough theoretical background in green infrastructure planning (such as conservation and urban planning, and integration with public participation). Finally, a third option would be students from land surveying programmes. They usually have relatively strong background in GIS and sometimes these programmes also contain courses in spatial planning. Considering the present programme availability and their content, probably a combination of a BSc programme focusing on either GIS or planning, and a MSc's programme focusing on a complementary subject area and providing theoretical knowledge would be of great benefit for acquiring many of the desired skills discussed in this paper. To implement the desired GIS knowledge into the planning organisations, on the other hand, may be another nut to crack. Friedman (2008, p. 254) quite bluntly describes planning as "a professional field that defines itself chiefly by its own technical competencies" and hence is not prone to accept knowledge from other fields. Furthermore, he argues, planners tend to use the variables they are familiar with through their earlier education and to use data that are readily available. To overcome this problem Van Assche *et al.* (2013) suggest that if academics want to influence planning practice analyses must originate from the actual problems which the practicing planners experience.

Municipalities are key actors for territorial planning

Implementing policies about green infrastructures requires comprehensive spatial planning across all land covers in landscapes and regions, and thus integration of multiple policy areas (SOU 2013:43). Combining conservation, management and restoration strategies can enhance biodiversity conservation in terrestrial, freshwater and marine ecosystems at all scales, thereby promoting their capacity to resist human-induced pressures and is therefore essential to deliver ecosystem services, and to reduce the resilience to expected climate change impacts (Thompson *et al.*, 2009).

In Sweden, municipal governments are responsible for planning to realize political and societal expectations related to sustainable development and sustainability (PBL 2010). Swedish municipalities have responsibility for the local environment in all their activities (Government Bill 1990/91:90). All municipalities must have an up-to-date comprehensive plan that should be an overall decision-making and action plan for the land and water use and for settlements development, and shall take into account national and regional objectives, plans and programmes relevant to sustainable development and sustainability. Thus, municipal decision makers in municipalities should take the lead (Stockholm +40, 2012). However, this requires that spatial planning can be characterised as a collaborative learning process. Elbakidze *et al.* (2015) analysed public-led spatial (i.e. comprehensive) planning in nine Swedish municipalities representing a steep urban–rural gradient in the Bergslagen region of Central Sweden. Unfortunately, attributes needed to support strategic spatial planning through collaborative learning were absent or undeveloped. This study concluded that there is a need for arenas promoting stakeholder engagement and participation, which combines both bottom-up and top-down approaches, and where evidence-based collaborative learning about landscapes social-ecological themes can occur.

Case studies of how GIS can support green infrastructure planning

Biodiversity conservation, together with climate mitigation and adaption, are two contemporary groups of wicked problems, which require a transition away from sectorial silos towards systems thinking with a landscape perspective (Angelstam, 2022). Here spatial data and analyses of those have a key role. Below we present a handful of examples of how GIS can support green infrastructure planning.

Swedish forest and environmental policy aim for example at conserving viable populations of naturally occurring species. The key assets for that are sufficient amounts of habitats forming functional green infrastructures that represent different land cover types. Spatial modelling of how the functionality of habitat networks varies in space and changes over time is one method that can guide protection, management and restoration of habitats. An important principle for the conservation of species in a landscape has the acronym "BBMJ" (Lawton *et al.*, 2010), which stands for Better, Bigger, More and

Joined. Studies of entire Sweden (Angelstam *et al.*, 2020) and particular regions (Angelstam & Manton, 2021) demonstrate the need to consider the entire portfolio of "BBMJ" principles. The rapidly increasing availability to open access data and open source computer programmes offers grand opportunities, but requires training.

A warmer climate leads to increased evaporation and increased water demand in plants, which in turn can lead to drought and greater risk of fires. However, warmer air can simultaneously contain larger amounts of water vapor than colder air, which can lead to heavier rainfall. Intense rainfall can lead to flooding. To predict, plan for and act under flooding events, analyses of geodata using GIS play a crucial role, and there are appropriate tools (Brandt *et al.*, 2021). However, lack of knowledge among planners about physical geography, GIS and maps can underestimate flooding risks. Brandt and Lim (2022) argue that the lack of such skills stems from the limited interest of the subject of geography as a cross-disciplinary subject in education programs. Three obstacles valid for Sweden are that geography is not a compulsory subject, geography is classified as social science in spite of biophysical dimensions being a key component, and geography is the subject that has the lowest proportion among all subjects of teachers with an appropriate education background.

Intense debates currently take place at different levels of society about forests and climate. It is urgent not only to strive for a halt to the increase in greenhouse gases in the atmosphere, but the levels need to decrease sharply. What are the opportunities to store carbon in a landscape? Angelstam *et al.* (2021) carried out an exploratory study to understand how an entire river catchment's (1882 km^2) stocks of carbon have developed during the past four centuries. This was based on analyses of spatial and statistical data about past and present site conditions, land use and land cover change. The analyses indicated that approximately half (48%) of the carbon present in the past "natural" landscape in the study area has disappeared during the last four centuries. Loss of grassland, dead wood and old-growth forest were the three main contributing factors. Restoration of stored carbon requires integration of both ecological and social systems, that is, what geographers call landscapes. This requires collaboration between different stakeholders and learning based on evidence and systems analysis.

Conclusions

Ample access to data and spatial modelling algorithms provides excellent opportunities for improvement of knowledge-based spatial planning and governance towards sustainability using GIS-based analyses and visualisations about the level of green infrastructure functionality. However, this requires that planners, landowners and other stakeholders acquire broader knowledge in different fields of knowledge, have appropriate data, and master education skills to make spatial analyses across entire landscapes and regions, as well as to communicate the results among stakeholders with different agendas. Thus, the planners are supposed to master (1) different technical aspects of GIS, (2) theoretical knowledge about the specific

planning task, and (3) skills in collaboration with specialists and stakeholders from different fields. All these three parts need be a part of planning education programmes. Hence there is need for new, or revised, education programmes including a broad spectrum of economical, ecological and socio-cultural dimensions of sustainability as well as knowledge about how society is steered, in combination with GIS as a tool for spatial analyses and visualisation.

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Appendix

Interview questions

Can you describe yourself and your work?
- – Age?
- – Number of years at the present work?
- – Title and tasks?
- – Education?
- What regulations or policies guide your work with biodiversity?
- What does biodiversity mean to you? Do you use any particular species in your plan-ning?

- Are you working with particular habitats?
- How large areas are you planning for con-cerning biodiversity?
- Do you model, make analyses or communi-cate with GIS and maps? Are there any pro-blems with data management or to get ac-cess to data that you might need for your work?
- Do you have the opportunity to develop your skills?

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