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GEOINFORMATICS | SHORT COMMUNICATION

Creation of subtropical greenhouse plan for the Flora Exhibition Grounds using GIS

Zdena Dobesova^{1*}

Abstract: This paper describes a cartographical and Geographic Information System (GIS) work on a poster for the subtropical greenhouse. The subtropical greenhouse is part of a collection of greenhouses in Olomouc that are located in the centre of the city (Czech Republic) near Smetana Park. An overall plan exists for the collection of greenhouses and botanical gardens in the area. We have created a poster regarding the subtropical greenhouse plan. Partial plan for the subtropical greenhouse shows the detailed positions of approximately 120 plants. This plan is central information on the big presented poster (format A0). Plans arose from the cooperation of cartographers and botanists using GIS. All digital maps and plans were created using ArcGIS software after punctual measure in the field. Beside text information on the poster, there are pictures of selected plants. They are accompanied with maps of their native range. The maps of the native range are original cartographical part of the same authors. The poster also contains an old proposal for the subtropical greenhouse, which was created by a leading garden architect, I. Otruba, in 1991 before construction of the greenhouse. The book regarding species in subtropical greenhouses was issued in 2013. It contains descriptions of 33 select species. The exposition represents mainly Mediterranean flora. Each species is described with text and includes illustrations of fruits, leaves, flowers, and habitus.



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She holds a PhD degree from Technical University of Ostrava, Faculty of Mining and Geology since 2007. Research interests are GIS, digital cartography, the visual programming language in GIS, scripting in Python for ArcGIS, spatial databases. She has several lectures for study branch Geoinformatics and Geography at Palacky University in Olomouc, Czech Republic. She is an author of 8 books and more than 70 articles from journals and conferences.

PUBLIC INTEREST STATEMENT

The design of greenhouse plan is a demonstration that the geoscience field has a wider application than only geography. The basic vector graphic was digitized using the geographical information systems. There are two most important parts of the area of greenhouses: the shapes of buildings and the positions and shapes of plants. Data could be used repetitively for different tasks. The article presents one printed output—big poster with the plan of the subtropical greenhouse. Other utilizations of the same data are also mentioned. One of them is the interactive web map of greenhouses with the detailed position of plants. Next utilization of the same data is on the plans in three botanical books about species in palm, tropical and subtropical greenhouses. The biggest advantage is using one source of digital vector data for several purposes. The results could be accomplished only by intensive cooperation specialists as geoinformatics and botanists.

Maps of the native ranges of each species are an original important part of the book. Greenhouses are open to the public, and students from Palacký University participate in botany and environmental lectures there. The visitors are tended to be intrigued by the astonishing variety of subtropical plants.

Subjects: Botany; Earth Sciences; Geography; Cartography

Keywords: GIS; biogeography; thematic map; native range; plan

1. Introduction

The collection greenhouses on the Exhibition Grounds are situated in Smetana Park, Olomouc. They have been declared to be cultural monuments. The greenhouses, together with the Palacký University botanical garden, are a part of the Union of Botanical Gardens of the Czech Republic (Figure 1).

The collection greenhouses consist of four separate greenhouses. The largest and oldest is the palm conservatory (Figure 2). The range and richness of the collections are among the largest and most interesting in the Czech Republic. The greenhouses occupy an area of approximately 4,100 m², of which 3,040 m² is open to the public. Every season, dozens of the most exotic species bud, bloom and spawn there. The greenhouses are open to visitors nearly year round.

The botanical garden belongs to Palacký University and neighbours the greenhouses. The garden area is approximately 5,600 m². The greenhouses and botanical garden create a unique area for spending time or learning, in addition to their classical function of conserving endangered species. Special botanical expositions are designed there as a part of the annual Flora Fairground.

The maintenance and education programs at the greenhouses and garden require the creation of detailed area plans and plant registries. Staff and students from the Department of Geoinformatics and the Department of Botany at Palacký University have created the BotanGIS information portal. Moreover, printed plans, posters and books have been produced. This article presents a poster that encompasses all of the interesting map documents regarding the subtropical greenhouse.

Figure 1. Location of Olomouc in the Czech Republic.



Figure 2. The entrance to collection greenhouses by architect J. Pelikan.



2. History and exposition of greenhouses

Before the current greenhouses, there was an orangery with beautiful wooden carvings. Its history dates back to 1886 when the wooden orangery structures were relocated from the castle park in Velká Bystřice to Smetana Park in Olomouc. It was built as the first palm greenhouse, with more than 90 types of tropical plants imported from Moravian castle greenhouses (Dančák, Šupová, Škardová, Dobesova, & Vávra, 2013b).

The conservatory expositions are divided into individual greenhouses according to the ecological requirements of particular plants, such as palm trees, cacti, tropical species and subtropical plants. Some species are represented by very old specimens, which have been grown over many years. The cacti and succulents collection is the most important and undoubtedly stands out nationwide. The subtropical crops, bromeliads and orchids collection is also of great importance. Tourists and professionals alike are attracted by the valuable cycad trees and *Ceratozamia* specimens, as well as many other dominant palm trees. Permanent specimens are tagged with a valid Latin name, family, distribution range and identification number (ID). This identifier can be used find information in the greenhouse plans and the BotanGIS database.

3. History and exposition of the subtropical greenhouse

The subtropical greenhouse is a typical 1980s construction. The original subtropical greenhouse project was created in 1991 by a leading garden architect, Prof. Ing. Ivar Otruba, CSc., who designed the exposition as an Israeli garden. The original plan is part of the presented poster.

The first plants (*Ceratonia siliqua*) were ceremonially planted in 1994 by the former Israeli ambassador in the Czech Republic. The current exhibition is the result of a systematic plan, which is conducted by gardeners who work for the Flora Exhibition Grounds Olomouc, JSC and cooperate with Palacký University, Olomouc. In 2012, the greenhouse received roof renovations (Dančák, Šupová, Škardová, Dobesova, & Vávra, 2013a).

The major plants in the composition come from subtropical zone across the world (e.g. the Mediterranean, Asia Minor and Australia), many of which are useful plants (Figure 3). Citrus fruits, which comprise a large portion of the exhibited plants, are spontaneous cultural hybrids of native species. In addition to commonly known species, such as mandarin, lemon and orange trees, less known citrus trees also exist, including *Citrus medica* whose fruit can grow to two kilograms and are used by the perfumery and confectionery industries.

The entrance is lined with Chinese plant *Poncirus trifoliata*, whose thorny shoots attract attention. This species is used as a rootstock for citrus. *Actinidia chinensis* is an interesting plant, with large,

Figure 3. Exposition in the subtropical greenhouse.



Figure 4. Carnivorous plants exposition.



felt-like leaves. Representatives of Mediterranean flora include fig trees (*Ficus carica*), olive trees (*Olea europaea*) and aromatic rosemary (*Rosmarinus officinalis*). Twigs from myrtle (*Myrtus communis*), a Mediterranean shrub, have white flowers and dark fruits, making them popular choices for wedding decorations. The pomegranate tree (*Punica granatum*) is a scarlet flowering species. In the back of the greenhouse, near the lake, a very popular seasonal exhibit, carnivorous plants, is managed by the Science Faculty and the Department of Botany (Figure 4).

Tomato-like fruits, known as kaki, grow on the Japanese persimmon tree (*Diospyros kaki*). The evergreen Australian tea trees (*Melaleuca*) represent another remarkable species, from which essential oils with unique bactericidal effects are extracted. The remainder of the greenhouse is lined with strawberry trees (*Psidium cattleianum*), which produce red-purple fruits with a strawberry flavour.

4. Methods for plan creation

Some examples of digital plans for parks, and arboretums using Geographic Information System (GIS) exist. GIS technology is helping community garden managers inventory, maintain, and manage their plant collections. Shields (2010) describes the Davis Arboretum of University of California, where GIS software catalogue and map more than 30,000 plants. Arnold Arboretum of Harvard University (2011) has web map application with point positions of plants above aerial photo. Plants are labelled by ID number or by scientific or common name. There is a possibility to switch between point symbols of plants according to family, country or plant size. The crown expression by polygons

is not used. Alliance for Public Gardens GIS and firm Esri published Alliance for Public Gardens GIS (2011) as a tool for creating a public garden GIS.

Some map solutions are used only a simple flash-based tree map like Kew Royal Botanical Gardens: Kew Gardens Map (2017). There is only reduced selection of visitor interesting trees. Very seldom is used the GIS for greenhouses or small detail botanical area.

Unfortunately, detailed documentation of the greenhouse collections, including the plant origins and ages, does not exist. It was destroyed by a fire in the Archives of the Exhibition Grounds, which occurred in the early 1990s. The remaining documentation was completely destroyed during the 1997 floods.

The only remaining subtropical greenhouse plan that still exists is the plan proposed by I. Otruba. This plan is presented in the poster. It contains suggestions for pavements, bridges, lakes and major plants. The contours are also mapped in the plan. The elevation difference between the entrance and rear of the greenhouse is more than 1 m. This elevated arrangement creates a more attractive exhibit. The basic arrangement of the greenhouse has remained unchanged, including elevated soils, bridges, and the lakes.

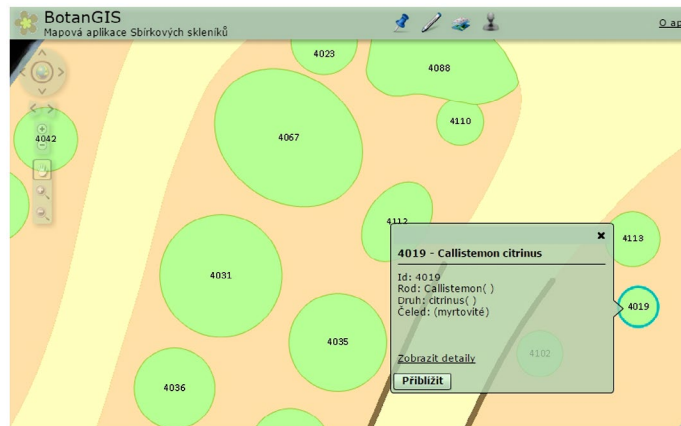
The discussion of geoinformatics-cartographers and botanists started before the creation of plans. Some problems also arose during digital plan creation. These questions were solved. What data to measure and digitize firstly, buildings and plants? What level of detail? How express the plants, by point or polygons? What is a correct shape of the polygon for plants to select, schematic or punctual? How assure the visibility of all plants, especially small plants under big plants in the plan? How many data-sets prepare in various scales for printed plan, poster, and interactive map? Next text describes the final solutions and procedures.

A systematic gathering of detailed greenhouse plans began in 2011. First, the greenhouse and botanical garden buildings were measured and digitized using ArcGIS. This resulted in an orientation plan for the entire area, depicting all greenhouses and botanical gardens without position of plants (Figure 5). Some technical building parts as heating, electricity, etc. were omitted. The main purpose

Figure 5. Collection greenhouses and Palacký University botanical garden overview plan.



Figure 6. Interactive subtropical greenhouse plan via the portal BotanGIS with a plant callout (www.botangis.upol.cz).



of the mapping is to better imagine expositions and produce a recommended tour route for visitors. The red line denotes the recommended route, which is coloured to attract attention within the plan.

The greenhouse and botanical garden plans have similar map keys. The colour and symbol choices mainly fulfil the cartographic associativity rule. Cartographers recommend green colours for parks and greenhouse expositions. Dark green is used for six rockeries in the botanical garden. Yellow was used for footpaths in both areas. Plant beds were rendered in brown (Dobesova, Vavra, & Netek, 2013).

The format of the plan is A4. This plan is used as overview map in the presented poster. The print version is available for visitors at the entrance to the greenhouses (both in Czech language both English language).

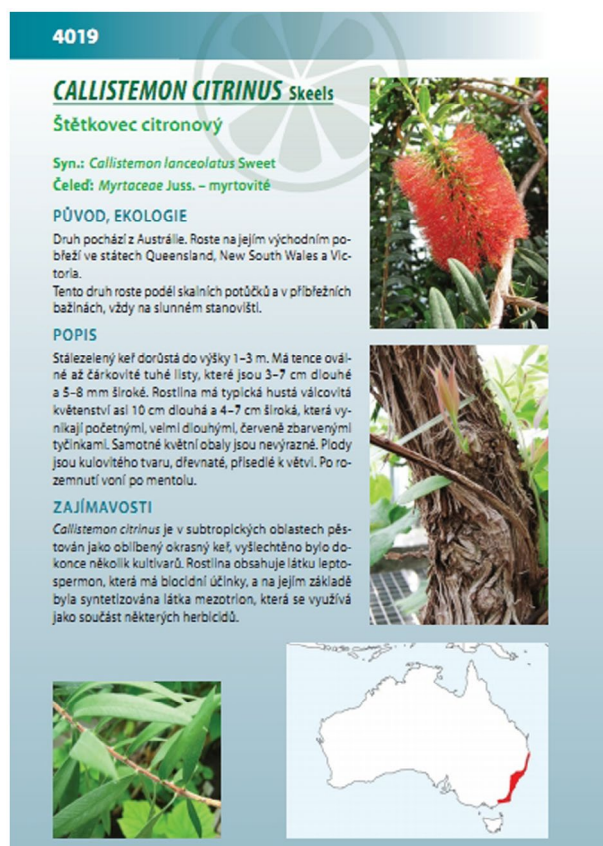
The second part of the project collected data regarding plant position and crown size. The greenhouse plants are drawn as circles or ovals, expressing the actual plant cover of each specimen. The plant list was stored in the database. Each plant received a unique ID number that identifies the plant in the database and plan. The plan and database are both parts of the BotanGIS botanical information system (www.botangis.upol.cz). The plant database is linked to the interactive plans (Figure 6). It is possible to search for plants based on ID, genus, family and other descriptors (Nétek, Dobesova, & Vavra, 2014). The same digital data-sets were used for printed plan, poster (Appendix A) and interactive map. The differences in scales are not so big to generalize data and to create separate data sets for each scale and type of plan output. The reusability of vector data is a big advantage of creation and storing data in GIS.

Three books were issued in 2003 regarding palm, tropical and subtropical greenhouses (Dančák et al., 2013a, 2013b, 2013c). Select species are described in these books. Each book contains a detailed plan of each greenhouse.

The subtropical greenhouse book contains both the original plan from 1991 and the contemporary plan, with a complete list of plants (Dančák et al., 2013a). The book describes only 33 species. These interesting plants are denoted in the plan using a dark green colour, while others are light green. In addition, some species have more than one individual plant in the greenhouse. In the book, each species is described by three paragraphs: distribution and ecology, morphology description and interesting facts about the species. Species are illustrated using photos of fruits, leaves, flowers and habitus (Figure 7).

Moreover, each plant is depicted by a native species range map. The definition of the *native range* of the species term is based on each plant species evolving at a specific place on Earth, where it

Figure 7. An example list of the Australian *Callistemon citrinus* species (Dančák et al., 2013a).



typically occurs at present. However, a large number of species have expanded into neighbouring and even distant areas. If they did so spontaneously, via natural processes and without human contributions, these areas are called *native ranges* (Pyšek et al., 2004; Smith, 1986; Webb, 1985).

All native range maps were created by cartographers at the Department of Geoinformatics, with help from botanists. A collection of 115 native range maps were created for the three above-mentioned greenhouse books (Dančák et al., 2013a, 2013b, 2013c). Some of them are original works. Native range maps are examples of chorochromatic maps. Chorochromatic maps only illustrate nominal data for specific areas using various colours (Kraak & Ormeling, 2003; Voženilek & Kaňok, 2011).

Experimental testing of visualization methods verified good understanding of chorochromatic maps (Pöddör & Kiszely, 2014). Two types of regional delimitations were used for the native range maps. If areas were well known and detailed in the botanical literature, we used a red polygon with a detailed outline (e.g. *Actinidia chinensis* and *Arundo donax* on the poster). At times, the coastline region became discontinuous and comprised islands (Figure 8). Accurately drawing the regions proved difficult, with botanists verifying the final accuracy.

If a native range was approximated, only a red oval outline was used (e.g. *Punica granatum*, *Citrus madurensis*, *Citrus sinensis*, *Citrus limon* and *Lycianthes rarnitonei* on the poster—Appendix A). Botanists were uncertain of all of the native ranges, especially for early domesticated crops. In these cases, they assumed or inferred the native ranges. Various visualization methods exist for approximating data (Brus, Vozenilek, & Popelka, 2013). Delimitation using smooth ovals is simple and comprehensive. Therefore, it is an effective generalization method.

Figure 8. Europe native ranges for *Ruscus aculeatus* (Dančák et al., 2013a).



5. The contribution of cooperation

The presented utilization of GIS is a cross-disciplinary example of cooperation between botanists and geoinformatics. Chain of discussions and partial solutions of problems resulted in the series of useful map results. One of the solved problematic tasks were the recommendations and the decision how to correctly expressed suitable shape of crowns of plants from the botanical point of view. Mainly circles and ellipses were chosen. The jagged snake shapes were used only sporadically in case of three bushes. The smoothed shapes were preferred. Exact detail shapes are not necessary. The shapes could be various due to the pruning of bushes and trees in seasonal maintenance. The form of the crow expression also respects the botanic tradition, that uses only simple circles for crowns. From the cartographical point, the unsmoothed shapes also disturbed reading of plan and have non-aesthetic impression.

We also solved the expressing of cover by plant crowns to be all visible in plans. ArcGIS served very helpfully by the operation *Sort* for polygon shapes. Descending sort according to polygon area moved smaller shapes higher to be visible in the plan under bigger crowns. Without botanists were not possible to decide the correct set of important plants to be inserted to the plans. Some plants are seasonal, and they were not included in plans.

The outcome of GIS research is that data collecting could be used for mapping in very detailed scale, as the position of plants in greenhouses. The distances between plants were sometimes in centimeters in reality. The next outcome is the experience with the multiple utilizations of the same data. One source of digital vector data (shapefiles) was used for several outputs: interactive map on the web, orientation maps in greenhouses as big posters, and maps in printed books about planted species. Both administrators of greenhouses and visitors use all maps in everyday work. The map outputs are helpful also for botanical education that takes place in the area of greenhouses. All these useful experiences increase the skills and knowledge in using GIS in the fields of mapping botanical objects.

5.1. Software

The ArcGIS for Desktop 10.2 software, which is produced by Esri, was used to create the following plans: the subtropical greenhouse plan, the collection greenhouse area orientation plan and the native range maps. The AutoCAD Map 3D Raster Design 2015 software, which is produced by Autodesk, was used to clean and de-skew the scanned, original plan from 1991. This old plan was necessary to prepare before presentation on the poster. Some speckles and pencil notes were there. All these unwanted scraps were cleaned. The poster was designed and printed using AutoCAD Map 2015. This software was powerful to collect and maintained all partial plans, maps, photos and texts to one big informational poster.

5.2. Data

The source data were taken from the “Data and Maps for ArcGIS” data-set, which is available in ArcGIS (Esri, 2015). Topographic data for the continents and political boundaries were used as base layers for native range maps. The data about position and crowns of plants were measured manually in the field.

6. Conclusions

The creation of the BotanGIS information portal provided a digital data-set for the collection greenhouses and botanical garden in Olomouc. The set was used to create a series of maps with several purposes and scales. The overview map contains all of the greenhouses, buildings and botanical gardens, as well as the main tour route. The detailed plans for each greenhouse depict plant locations and crown shapes. The use of ArcGIS to store and illustrate the data allows for the publication of plans in different forms. The first form is the interactive BotanGIS portal. The second form is the plans printed in the three books. Finally, plans were used as important poster features (format A0).

The content of poster for subtropical greenhouse is depicted in this article and presented as Appendix A. Posters were placed near the greenhouse entrances. ArcGIS was also used to produce native range maps.

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SUBTROPICAL GREENHOUSE
FLORA EXHIBITION GROUNDS OLOMOUČ, JSC.

4013 <i>Auriclea domus</i>		
4025 <i>Avis arvensis</i>		
4027 <i>Citrus limon</i>		
4035 <i>Actinidia chinensis</i>		
4040 <i>Citrus sinensis</i>		

[illegible]

The diagram is a site plan of the University of Toronto campus, showing various buildings, green spaces, and parking lots. The plan is color-coded according to a legend: red for 'University of Toronto', green for 'Parkland', yellow for 'Grassland', orange for 'Grassland', blue for 'Water', purple for 'Water', and brown for 'Water'. The plan also shows 'Entrance' and 'Exit' points, and a 'University of Toronto' logo. The plan is oriented with North at the top.

[illegible]

PLAN PROPOSED BY PROF. IVAR OTRUBA IN 1991

PALACKÝ UNIVERSITY OLOMOUČ
Department of Geodesics
Czech Republic, 2015

Photographer: M. Martinková, H. Šapová
Editor of supervisor: M. Dancák
Cartographer: Z. Blatenská, A. Váňa

 **BotanGIS**



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