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IMPROVING SEN2CUBE.AT WEB APPLICATION VISUALIZATION CAPABILITIES

Diploma thesis

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ANNOTATION

The purpose of the thesis is to improve the visualization capabilities of Sen2Cube.at a web application for visualizing images considering advanced cartographic methods and a User-Centered approach. The research begins by understanding the current condition of Sen2Cube.at system through user evaluation, internal discussion, and SWOT analysis. Then, formulating Sen2Cube.at visualization capabilities thresholds concept and transforms it into practical guidelines and image map models. The last part of this thesis focuses on developing User-Centered geovisualization tools that are needed by the current users, particularly in terms of inferring the semantic enrichment image maps. There are two visualization tools proposed through the UI prototype. Both theoretical concept and practical result of this thesis might be a basic concept for further development of visualization tool in Sen2Cube.at web application.

KEYWORDS

This thesis has been composed by *Zealandia Sarah Nurul Fatma* for the Erasmus Mundus Joint Master's Degree Program in Copernicus Master in Digital Earth for the academic years 2020/2021 and 2021/2022 at the Department of Geoinformatics, Faculty of Digital and Analytical Science, Paris Lodron University Salzburg, and Department of Geoinformatics, Faculty of Science, Palacký University Olomouc.

Hereby, I declare that this piece of work is entirely my own, the references cited have been acknowledged, and the thesis has not been previously submitted for the fulfillment of the higher degree.

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Theses guidelines

Sen2Cube.at as the prior remote sensing web application offer the opportunity produce semantic enrichment product particularly for Sentinel 2 remote sensing data leave space for improvement regarding levitating user experience particularly inferring the image map products. Therefore, this thesis aimed to develop a set of tools and capabilities of the Sen2Cube.at web application for compiling image maps from Sentinel data regarding to advanced cartographic methods and user-centered approach. Through this thesis a series of assessments under applied workflow is established in order to improving geovisualization capabilities of Sen2Cube.at web application.

Concerning this matter, determining the thresholds in the workflow of the web application were attempted by system examination and SWOT analysis, followed by user evaluation assessment become an input to understand the Sentinel semantic image map that they pursue to. Those three assessments are representing the initial communication between the Sen2Cube.at and end-users to create set of tools that user-centered under incorporate with end-users completely through the geovisualization tools development process.

Based on previous stage, a highlight of desirable features is produced as a graphical concept prototype including the visualization concept and the thresholds in workflow of creating image maps. During this stage, a conceptual discussion is conducted to understand the system capabilities in order to figuring out user issues based on the previous user evaluation assessment. Afterwards, a followed prototyping process is arranged for developing the geovisulization set of tools in practical. During the prototype developing process, the tools are discussed through formal and informal meeting communication with the Sen2Cube.at team.

All together the conceptual result of this thesis allows to draw conclusions of user-centered geovisualization tools that needed by the current users particularly in terms of inferring the semantic enrichment image maps. The tool prototype itself as the practical result of this thesis might be a basic concept of developing visualization tool in Sen2Cube.at web application in order to showcase the advance cartographic method of image map visualization.

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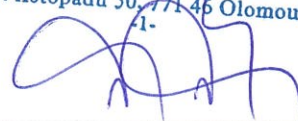
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CONTENT

LIST OF ABBREVIATIONS

Abbreviation	Meaning
API	Application Programming Interface
CSV	Comma-Separated Values
EDA	Exploratory Data Analysis
EO	Earth Observation
GEOTIFF	Geostationary Earth Orbit Tagged Image File Format
GIS	Geographic Information System
GUI	Graphic User Interface
Hi-fi	High fidelity
ICA	International Cartography Association
Lo-fi	Low fidelity
Mid-fi	Mid fidelity
ODC	Open Data Consortium
QGIS	Quantum-GIS
SIAM	Satellite Image Automated Mapper
SWOT	Strength, Weakness, Opportunity, Threat
UI	User Interface
UX	User Experience
WMS	Web Map Service

INTRODUCTION

Cartography takes an important role in improving user experience by combining it with web map design. Understanding the user needs is an important value regarding creating an interactive and efficient web map application. Acknowledge the user's characteristics and background, which affect their ability to perceive and/or to comprehend the geographical information inherent in the map, is not only relevant for the design and development of cartographic tools for the web (Kraak & Brown, 2001).

A data cube is a new approach to organizing and managing multidimensional data, in Earth Observation (EO) domain, satellite imagery stored in a server on each pixel is associated with coordinates. EO data cube proposes a possibility to tackle big data challenge by translating the coordinate position from the digital globe to the internal file structure, collecting the images, and conveniently presenting them as continuous maps (semantixcube.net). Furthermore, EO Data Cube also makes it possible to do such as processing satellite imagery into semantic enrichment information on the fly. By combining EO data cube and website technology, semantic enrichment satellite imagery could be produced and visualized as a web map directly in the web application system.

Sen2Cube.at is the first remote sensing web application designed as a general-purpose semantic Earth Observation data cube on the fly, particularly for Sentinel 2 imagery. Users do not need technical programming skills to collect this semantic information. By providing Graphic User Interface (GUI), user-defined image query could be obtained through the website and retrieve spatio-temporal information directly in the resulting interface as an image map and possibly download as raster data (GeoTIFF), WMS link, or QGIS project. Along with the rising number of active users, improving the image map visualization has become an emerging step toward enhancing the web application user experience. Instead, continue in any spatial desktop software to refine the image map result, to do it in the same environment as the analysis process goes will be a plus value of Sen2Cube.at.

Through this study, we try to examine the user's needs in due to improving user experience by performing user evaluation followed by developing visualization and cartographic tools both as concepts and a prototype by taking case of Sen2Cube.at web application. User evaluation, including SWOT analysis and user questionnaire for determining the threshold of web map visualization. Both results will be input to generate concept and create the visualization and cartographic tools prototype as the suggestion for Sen2Cube.at team in due to improving visualization capabilities.

1 OBJECTIVES

This thesis aims to design concepts for improving the visualization capabilities of web-based big EO data analysis results, taking a case of Sen2Cube.at web application by considering advanced cartographic methods and User-Centered approach. Sen2Cube.at as the prior remote sensing web application, offer the opportunity to produce semantic enrichment product, particularly for Sentinel 2 remote sensing data, leaving space for improvement regarding levitating user experience to inferring the image map products. Through this thesis, a series of assessments under applied workflow is established in order to improve the visualization capabilities of Sen2Cube.at web application.

Concerning this matter, determining the visualization capabilities thresholds is attempted by SWOT analysis together with user evaluation assessment, both become an input to understand the Sentinel semantic image map that they pursue. Those assessments represent the initial communication between the Sen2Cube.at and end-users to create a set of tools that are user-centered completely through the geovisualization tools development process.

Based on the previous stage, a highlight of desirable features is produced as a graphical concept prototype, including the visualization concept and the thresholds in the workflow of creating image maps. During this stage, a conceptual discussion is conducted to understand the system's capabilities in order to address user issues based on the previous user evaluation assessment. Afterward, a followed UI prototyping process is arranged for developing the geovisualization set of tools in practice.

Altogether, the conceptual result of this thesis allows drawing conclusions about User-Centered geovisualization tools that are needed by the current users, particularly in terms of inferring the semantic enrichment image maps. The tool prototype itself, as the practical result of this thesis, might be a basic concept for developing visualization tools in Sen2Cube.at web application in order to showcase the advanced cartographic method of image map visualization.

2 METHODOLOGY

2.1 Methods

This study applies mixed methodological approaches to address the objectives. A general method includes system examination, conceptual development, and prototyping. To address the first objective, which is determining Sen2Cube.at visualization capabilities thresholds, Sen2Cube.at system examination is performed. The second objective is establishing the visualization capabilities concept based on the previous step. A concept of the image map and cartographic tools are expected as a result. In order to improve the visualization capabilities, a certain prototype of the image map and cartographic tools is developed as the final result of the study.

2.2 Used Software

There are several supporting web applications and software employed for this study based on the result of the objectives. LimeSurvey is the main web application conducting the questionnaire and analysis of the respectful result, particularly for making the questionnaire form and statistical analysis afterward. An in-depth interview was arranged in video call mode by using the WebEx platform, which allows to record during the interview. In order to create the image map models, substitution between ArcgisPro and QGIS are employed. The work of making map layout and symbology guidelines used Inkscape graphic editor software. Visualization tools UI prototype as the last part of the research is created using Figma web application for both the animation and paper document format.

2.3 General Workflow

The general workflow is adopted from Anthony et al. (2005) study for designing geovisualization tools for epidemiology which is a modification of a similar study by Slocum et al. (2003). Anthony et al. workflow highlighting user incorporation across each stage. However, to accommodate the study goals and current technical development, a modification of the Anthony et al. procedure is applied. Figure (1) illustrates the general workflow of this study.

Work domain analysis refers to the initial communication of ideas and Sen2Cube.at recent visualization capabilities. This includes formal and informal meetings with Sen2Cube.at developer along with SWOT analysis. The purpose of this stage is to get the internal perspective of Sen2Cube.at web application. In order to understand the user's need/ external perspective, user evaluation is conducted. By doing both, a holistic understanding is formed as the key to creating a concept of visualization capabilities improvement.

Conceptual development represents the underline desired features that come Sen2Cube.at system examination. During this stage, the report from work domain analysis and user evaluation are combined to create a concept for creating user-centered visualization capabilities of Sen2Cube.at. The conceptual design then turns into practice through the prototyping process. The visualization capabilities concept is divided into two main parts: image maps and cartographic tools. Both include several suggestions from a cartographic point of view which are implemented as graphical prototypes.
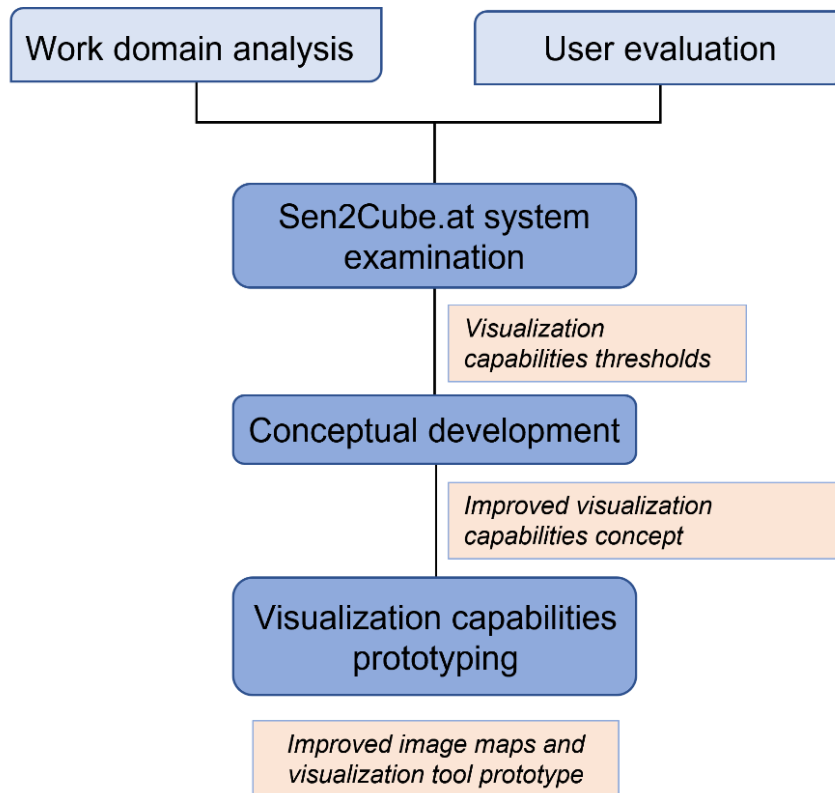
Figure 1. Thesis general workflow

2.4 Sen2Cube.at Web Application System

Sen2Cube.at is the first remote sensing web application designed as a general-purpose semantic Earth Observation data cube on the fly, particularly for Sentinel 2 imagery. Users do not need technical programming skills to collect this semantic information. Semantic EO data concept refers to spatio-temporal data cube consisting of EO data, in which for each observation minimum of one nominal interpretation is available and allows to be quired in the same instance (Augustin et al., 2019). By providing Graphic User Interface (GUI), user-defined image query could be obtained through the website and retrieve spatio-temporal information directly in the resulting interface as an image map and possibly download as raster data (GeoTIFF), WMS link, or QGIS project. The user target is intermediate experts in a specific field of expertise and would like to use remote sensing imagery to support their work. Semantic enrichment product is inferred from three main parts: **knowledgebase, factbase**, and **inference** (figure 2). **Knowledgebase** contains semantic models formed as combined blocks of general or specific knowledge of the world. The user could define what they would like to infer based on the model that they built in this section or use preserved model blocks such as 'Urban Green Areas,' 'Vegetation vs. Baresoil,' and 'Cloud Free Composite'. Inside the building block, the result of the inference process will be defined as well, there are two main options; image map or statistical graph, depending on the analysis process. **Factbase** refers to AOI and time interval query. A spatial subset can be drawn directly on an interface map by point, line, or polygon. Alternatively, upload the GeoJSON dataset or the URL link. AOI can be in more than one location. Regarding the result, Sen2Cube.at system allows the verb "group by" as the action for grouping the result based on each

location. The temporal subset allows the user to choose a certain period of Sentinel 2 recording (July 2015 – until now).
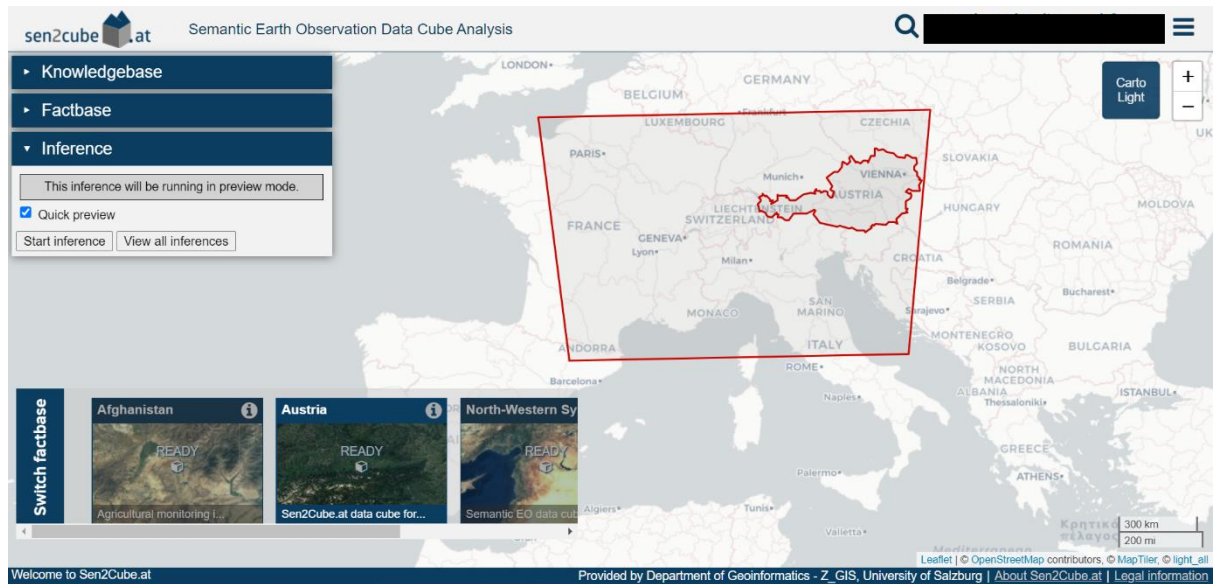

Figure 2. Sen2Cube.at UI (source: sen2cube.at)

Once the model, AOI, and time interval are set, the semantic query can be executed by clicking the start **inference** button under the Inference box. The inference box also contains information about the query process, success, or error that appears shown in this box. After the query is done, the user can refer to the 'view result' or 'preview' window to see the result (figure 3). 'view result' means that the image map will be shown as original spatial resolution, and for preview-mode, the spatial resolution will be reduced by a factor of 10, which reduces the processing time faster. The preview mode can be identified by the preview banner at the top of the page. The result of inference can be spatial data (map) or non-spatial data (graph chart). Sen2Cube.at web focus on generating EO semantic enrichment information in the web environment. All the process is supposed to work on the fly based on data cube technology. In general, the visualization of the image map is all in default color ramp, ranging from dark blue-ish to yellow-ish color. Nevertheless, once the process is done, the view result or preview window becomes a fundamental GUI for the user to understand how well their product is executed. Therefore, cartography plays an important role here in delivering the information between the system and the user.
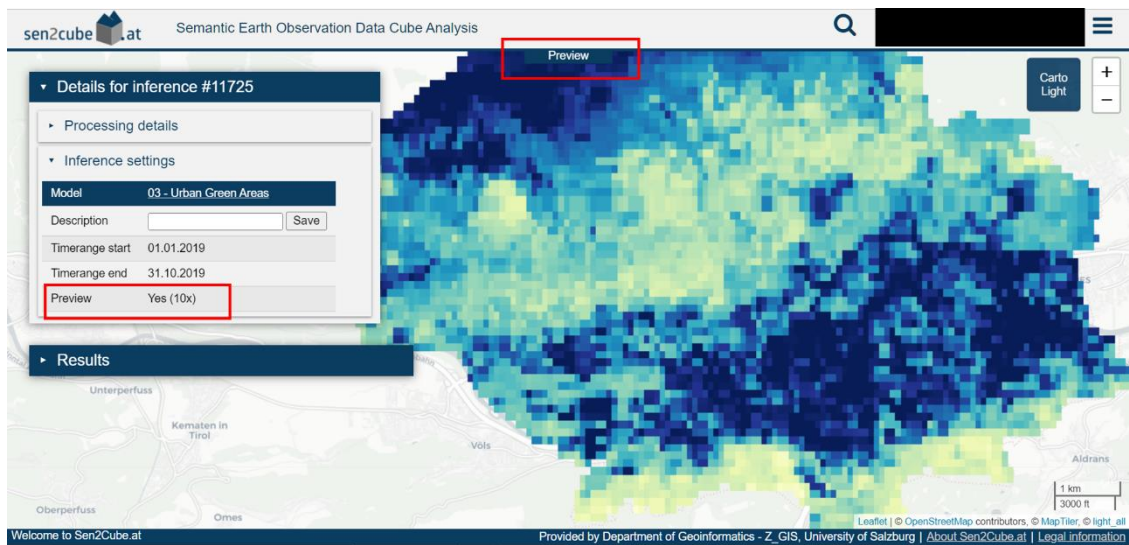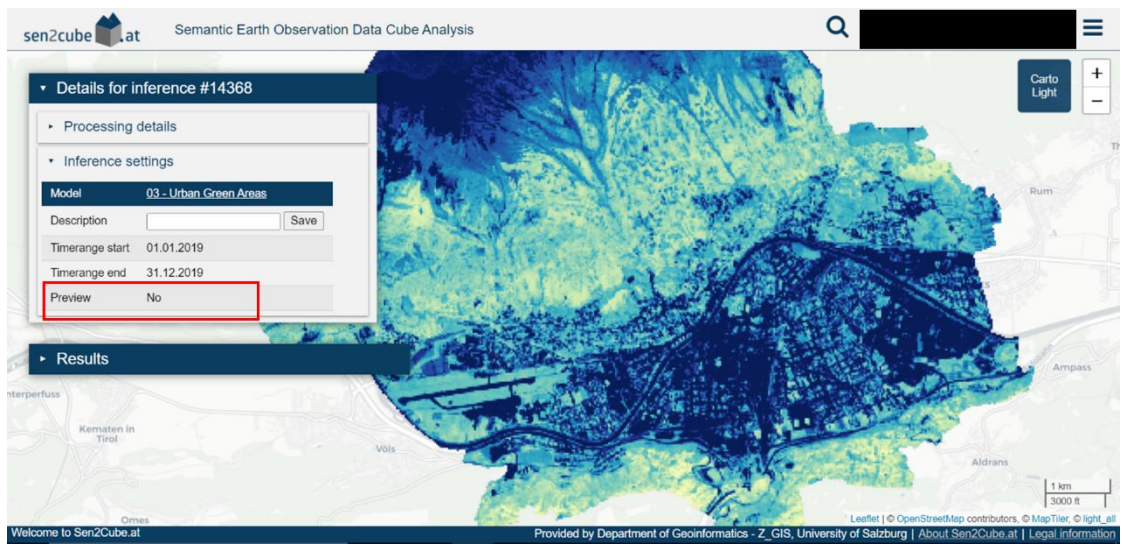
Figure 3. View (above) and Preview mode (below) window (source: sen2cube.at)

3 STATE OF ART

Web Cartography

The shifting map medium from paper to website platform affects the usability of the map itself. Paper-based map defines map use as providing insight into geospatial patterns and relations that are being produced by map producers (Kraak & Brown, 2001). In this environment, the audience is still under the term of map reader, and the activity of the audience is limited to some degree of interpretation (find a location, geospatial patterns, and relations). With the current development in website performance, the term map audience shifts into map user rather than map reader (Muehlenhaus, 2013). Web Map applications mostly use the dynamic element of the map that reflects the interactivity function of web application. Users could be more flexible in manipulating and changing the map view based on their preferences.

Web map can also be defined as the new medium for presenting maps besides paper. A map that is viewed in website medium emerged new trend of cartography that offers many opportunities, one of those is interactivity. Kraak & Brown (2001) defines web map in a specific application-dependent context is influenced by four main actors: user, provider, the viewing environment, and the map contents. The interaction between those actors will define the typical web map appearance. Interaction could be in various forms, depending on the objectives of the web map provider, it can be ranged from panning-zooming map, selecting layers, or manipulating geospatial data. All these options of interaction make it hard for web map providers to know how their maps will appear and who is looking at them. Therefore, understanding the audience is key in creating a web map.
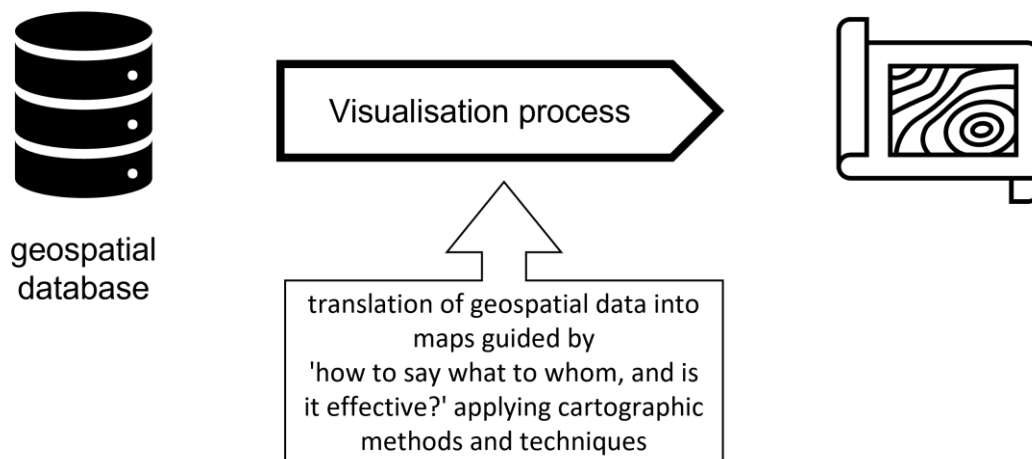

**Figure 4. Cartographic visualization process
(source: Kraak & Brown,2001 with modification)**

Geospatial data handling process phases consist of data acquisition, storage, manipulation, and visualization process. In this context, the visualization process is defined as the translation or conversion of geospatial data from a database into a map-like product (Kraak & Brown, 2001). Specifically, cartographic methods and techniques have taken part during the visualization process. Thus, the visualization process depends on where the visualization takes place in the geospatial data handling process phase depends on where the map will show up. It can be a 'quick and dirty' preview of database during geospatial analysis, or as a geospatial phenomenon real-time display (e.g., weather). Nevertheless, in any phase the visualization will be put into, the guidance of the cartographic visualization process is illustrated by Kraak & Brown (2001) (figure 4); 'How do I say what to whom, and is it effective?'. What cartographic methods, techniques, and medium are referred to as 'How'. 'I' means the web map provider, in this case, can be a cartographer or a discipline expert. Geospatial data graphics and semantics is included in 'Say'. 'What' is dealing with geospatial data and its characteristics. 'Whom' is the audience of a web map with the purpose of the map, e.g., a map for scientists is different compared to a map for children.

A visualization process is influenced by many factors. In the context of geospatial data, such as data scale, semantics, and type of data are impacted in the way designing maps, both map paper and web map. Along with the development of website technology, interactive web map also develops a new capability for the user, rather than just 'view' map, users nowadays are able to select geospatial data, produce geospatial analyses and visualize that satisfies them. Kraak & Brown (2001) stated that such a map had started a new completely role: a map is more than a communication tool but also a tool to guides user's visual thinking process. One of the acceleration factors is open access to abundant geospatial and non-spatial data on the internet.

Easy access to many and free data affects how geospatial data are visualized, and it is called visual geospatial data mining. Thus, had given the word visualization an enhanced meaning. This shifted meaning challenges users in web maps with the possibility of instantaneously changing the appearance of the map, which accommodates interaction and dynamics at the same time.

Human Map Interactivity

Nowadays, web map technology emerges human-map interactivity more than panning and zooming maps but further to changing, manipulating, and creating a map based on their own preference. Morrison (1997) stated that by using electronic technology, the map user no longer depends on what the cartographer put on the map. Now, map users are also able to produce analyses and visualization on their own. Since cartography deals with design, production, and use of maps, this new terminology of map audience became a crucial aspect of improving the effectiveness of map communication between user and producer in the website environment through User Interfaces (UIs). The process of the map becomes more than decoding and encoding between map producer and user. Nevertheless, the main function of maps remains to inform about geographic reality. Effective and interesting map design still takes part in this environment. By all means, the role of the cartographer in designing maps in a website environment is still crucial. As a result, cartography research incorporated with GUIs design arose within the rising use of web maps. ICA as the international board for cartographer association, developed keywords for the research agenda in cognitive cartography, particularly in the usability domain, which covers a range of issues that connect between humans and

geospatial data representation, processing, modeling, and analysis. Furthermore, based on Roth (2015) study mentioned the future opportunity of integration between cartography and the UI/UX design field. The same study also emphasizes aesthetics, emotion, and style to the effectiveness of a map till relevant in the web cartography era. It is also suggested additional research to generate and evaluate alternative cartographic interface design styles among web mapping applications.

Web Map Use Goals

MacEachren and Kraak (1997) illustrate the goals of map use as down below (figure 5). They differentiate the goals of map use based on three axes: audience, interaction, and data relations. Each ax shows the degree of task that will classify map use goals 'to explore', 'to analyze', 'to synthesize', or 'to present'. However, a web map may occupy any position in the three-dimensional space defined by these axes, depending on what a user does and the purpose of the web map.
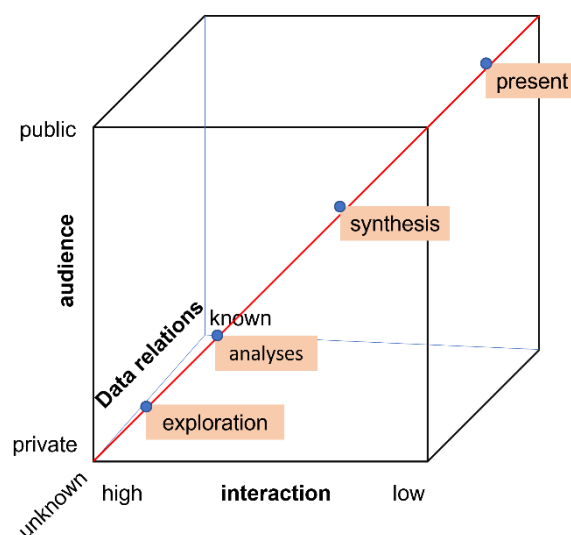

Figure 5. Map use goal cube
(source: MacEachren & Kraak, 1997 with modification)

Around two decades ago, the 'to present' task may take the majority of web maps by scans of existing paper maps into static view on the web. Generally, the audience for this kind of web map is a wide group of users with a general-purpose, this type of use mode can be found in the digital library, where usually they store the physical paper maps and scan those maps into a web map. Nowadays, a website is typically a medium for private use, a web visitor usually has their own purpose while visiting such web, which defines the use mode near the middle of the bottom side or the back of the cube. This type of web may provide medium interactivity and presenting of known geographical data such as switching layers of map details on and off and selection of colors symbology in such known geographical area. Alternatively, users may change the map orientation, scale (zooming), or area of interest (panning). Regarding 'presenting knowns to revealing unknowns' axis defines different conditions of map use. Users know exactly what geographical information that they are looking for, in this case use mode tends to 'presenting knowns', on the 'revealing unknowns', users carry a question that they want to solve through the website. Considering the recent website developments (data cube, client-server architecture, fast data query), the map use goal occupies the left-hand

bottom front corner of the cube (Kraak & Brown, 2001). This position is exploratory cartography: private use, revealing unknowns, and high human-map interaction. It became possible for users to explore and interact intensively with particular geospatial data in order to gain insight while using modern cartographic visualization techniques. Furthermore, the possibility of users creating their own map by doing geospatial analysis, modifying cartographic representation methods, and displaying the result instantly on the website is foreseeable. As such, modern cartography must adapt the website technology in order to improve the user experience of web map applications. As a consequence, the study for particular web map services is needed, particularly measuring the UX/UI interaction. One of the methods for measuring the user experience is a subjective evaluation of users. This method is effective in getting the desired feedback on a particular case with a specific respondent (Sterba et al., 2014). Considering Sen2Cube.at web application system, this type of evaluation is a suited method to improving the visualization capabilities.

User Interface and User Experience (UI/UX)

As many maps today are displayed on a screen, either PC or mobile, interactivity has become a fundamental key for delivering spatial information to website users. Users communicate through the interface and complete tasks through interaction. UI and UX can be separated under their focus on interfaces versus interactions. An interface in digital mapping is a tool that enables users to manipulate maps and desired geographical information (Roth, 2015). Interaction refers to two-way dialogue between user and map mediated by a computer device (Roth, 2012), in this case, a website platform. Guillory, & Sundar (2014) conclude interaction is both contingent and empowering. Contingent refers to two-way dialogue triggered by requests from the users. Empowering is allowing the user to modify the geographical information depending on their preferences. Therefore, users use interfaces simultaneously to experience interactions which experience determines the success or failure of an interactive product (Norman, 1988). A study by Roth (2013) stated interaction is the fundamental complement of representation in cartography together with theoretical and practice research. Further, he divided cartography research topics into two continua which are represented as a cartesian diagram: cartographic representation versus cartographic interaction and mapmaking versus map use (figure 6). Cartographic research might focus on one axe or a pinpoint somewhere in between as a combination. Therefore, this diagram should be interpreted as fuzzy boundaries with possibly a fusion among four coherent axes (Roth, 2013). UX and UI design topics in cartography research are placed close to interaction axe rather than opposing between mapmaking polar and map use axes. However, both UX and UI design processes include user-centered evaluation and applying methods that are established in the usability study domain (Roth, 2015).
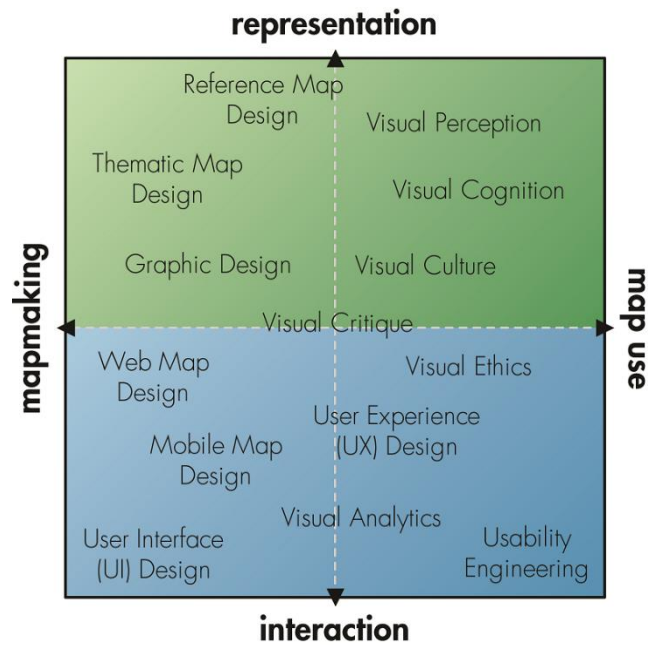
Figure 6. Cartography research diagram (source: Roth,2013)

Adapting from Norman's (1988) framework of the map interaction concept, Roth (2017) describes the UX design of website applications into seven stages. UX design takes into account Interaction primitives at whole stages. Taking the case of tornadoes time-series digital maps, Roth (2013) observes each stage interaction alongside with UX solution, as shown in Table 1.

Table 1 Roth UX interaction stages with a case scenario of tornadoes time-series digital maps.

Stage	Digital Map	Breakdown observation	UX solution
Forming goal	"I want to explore long-term patterns in tornado activity."	The user's goal is not supported by the interactive.	Complete a needs assessment to define user goals
Forming the intention	"I will start by seeing if the frequency of tornadoes has changed since 1950."	The user cannot complete one or several low-level tasks or relies on map reading alone to complete low-level tasks without interacting.	Develop use case scenarios based on low-level tasks
Specifying and Action	"I will the sequencing controls to advance the timeline by decade from the 1950s to present."	User does not understand how the present interface function supports his/her goal and intention.	Configure the map with smart default to show how the UI and map relate.

Executing the Action	"I use the mouse to move the slider widget from beginning to end."	User does not understand how to submit information to the interface through the input devices.	Improve flexibility to support multiple devices.
Perceiving the System State	"I See that the map now has more tornado tracks on it."	User does not notice how the map changed due to the interaction.	Provide summary information to compare before and after interacting.
Interpreting the System State	"I think that means that there are now more tornadoes today than there were in 1950s."	User does not understand what the change in the map means.	Combine visualization with statistical computation to highlight significant insights.
Evaluating the Outcome	"I now will modify my goal from a broad exploration of long-term patterns across tornado activity to analysis of specific causes of the increase."	User does not receive information from the interaction that he/she applied to achieve their goal.	Support enabling operators to collect insights during interactions (e.g., save, annotate, export).

UI Prototype

Prototype in UI design field refers to an iterative analysis technique of mocking up the UI of the system with actively including users through the process (Ambler, 2004). Prototyping UI has several purposes, such as an analysis artifact to explore the problem space of the system, a medium for communicating the possible UI designs of the system, and a design artifact that allows the developer to explore the possible solution of the system. The process itself can be illustrated under four high-level steps. The first step is analyzing the UI needs of the users. By understanding the user needs, the design will automatically work as a User-Centered paradigm.

Once the needs are met, designing a Lo-fi (Low fidelity) prototype might start often. This second step is also called paper prototyping which a web designer creates a concept of UI on the paper. By doing this, the concept of UI design is being validated. The next step is creating the digital prototype, which includes the interaction within the system called Hi-fi (High fidelity) prototype. Hi-fi prototype is good for evaluating complex interactions such as following certain task flow. To do so, using prototyping tools is helpful to execute the interaction in practice. Additionally, the UI design is also being tested (colors that are being used, intuitive aspects, placement of buttons or features). In this stage, a wireframe is involved. Wireframe in UI is a layout of a product that visualizes what interface elements will exist on the web (ACADEMY Designerrs, 2021). A wireframe is a crucial step of the interaction design process. There are three different types of wireframes which similar to UI prototype types: Lo-fi, Mi-fi, and Hi-fi wireframes (figure).

Lo-fi refers to a paper wireframe that contains a rough structure of functions, contents, headings, and topics. Often this type of wireframe is created on paper with a wire that connecting to each interface will look like while executing the task flow. Mid fidelity wireframe is the most common wireframe used for communication between stakeholders and end-users of the web system. Compared to the previous type, the Mid-fi wireframe contains UI elements in a more accurate way, such as in correct structure without the detail of chosen color. The last type is the Hi-fi wireframe as the most accurate and almost similar to visual design screens without so much of colors. The combination of wireframe and prototype will create a mock of interaction within the system. The last step of UI prototype is an evaluation by the stakeholders to verify what has been built. In this last part, the iteration of evaluate-edit will significantly be happening until find the evaluation process is no longer generating new ideas or solutions. Prototyping in the early stage of building the system is beneficial for stakeholders in due to tackle issues that might appear in the User Experience and provide the web designer navigation and confidence to move to the next step.
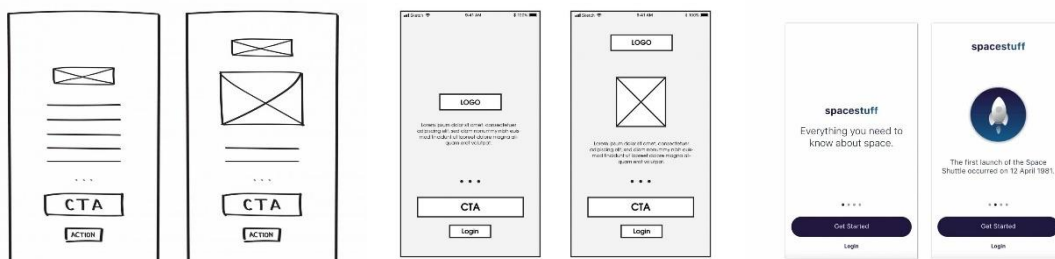

Figure 7. From left to hand Lofi, Mid-fi, Hi-fi wireframe
(source:https://mentormate.com/blog/low-fidelity-wireframes-vs-high-fidelity-wireframes/)

Data Cube in Earth Observation

Free and open access data, particularly in the satellite Earth Observation (EO) domain, has been emerging since Landsat opened their access to a broader audience around the world in 2008. Many scientists, academia, and even more government institutions are benefitted from this abundance of resources. Within a huge number of satellite images archived in big data infrastructure, to access and utilize those imageries might be a challenge itself.

Data cube, as part of cloud-based technology, is the new approach to organizing and managing multidimensional data, in EO domain, satellite imagery is stored in a server, in which each pixel is associated with coordinate and time (spatio-temporal). EO data cube proposes a possibility to tackle big data challenges (volume, variety, and velocity) by translating the coordinate position from the digital globe to the internal file structure, collecting the images, and conveniently presenting them as continuous maps (semantixcube.net). Therefore, the harnessing data process could be fast and effective. Furthermore, EO Data Cube is also possible to do such as processing satellite imagery into semantic enrichment information on the fly, which is a foremost ability offered by Sen2Cube.at.at web application. By adopting the data cube system, stored sentinel-2 satellite images can be derived and queried 'on the fly' while web processing the request, in Se2Cube.at allows to request, derive, query, and produce information from those stored sentinel-2 images into a higher semantic level (figure 8).
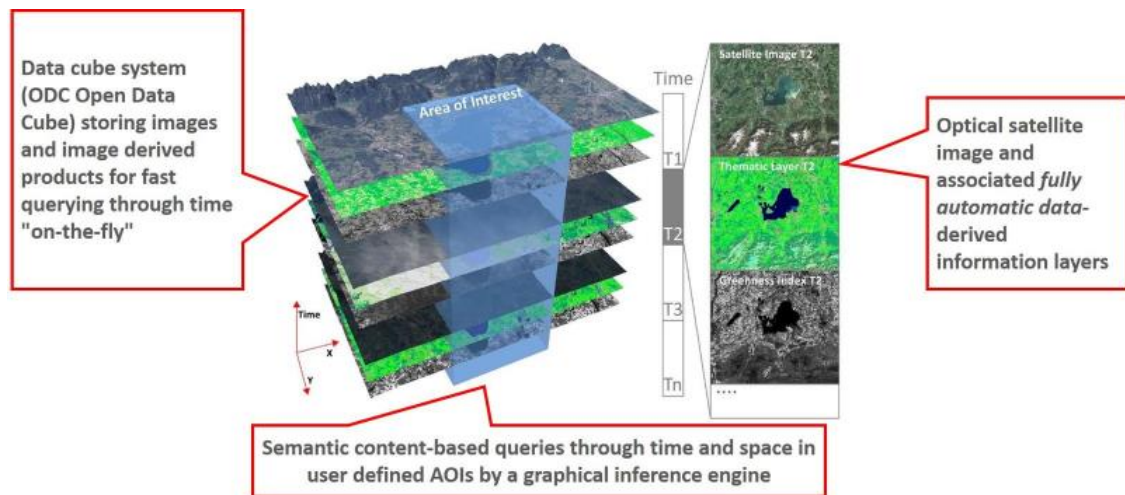
Figure 8. Sen2Cube.at data cube concept (source: sen2cube.at)

Sen2Cube.at system proposed EO data cube architecture that implements the computer vision in EO data cube into an explainable artificial intelligence approach (Sudmanns et al., 2021). The focus of semantic EO data cube is to provide a tool to generate specific and flexible information from satellite data that potentially leads to some degree of knowledge (Augustin et al., 2019). The approach relies on semantic enrichment automation incorporated with an interactive web-based GUI. Moreover, demonstrates the capability of semantic EO data cube potentially being scaled to a wider scale, such as a national scale. The interactive tool allows users (ranging from EO beginners to experts) to query semantic information from their own analysis through semantic inference model block builder without requiring programming skills.
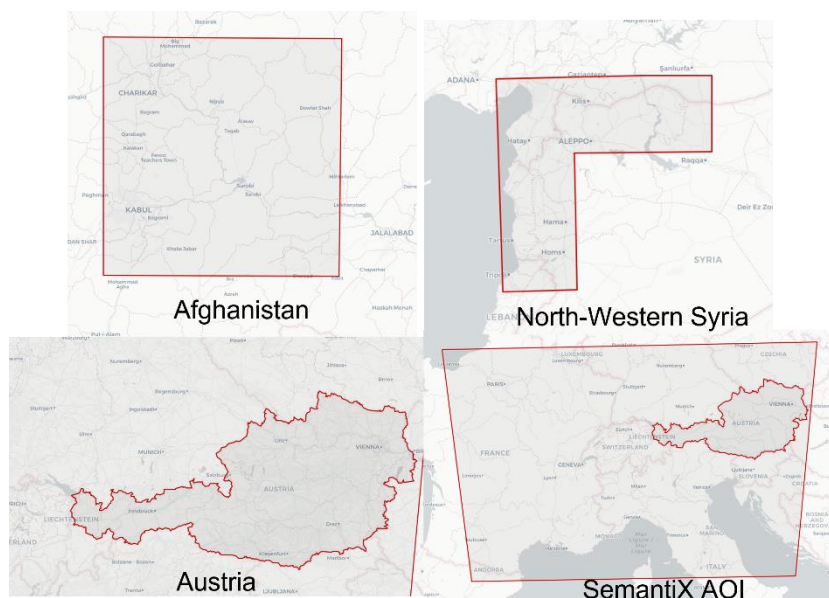

Figure 9. Factbase in Sen2Cube.at web applicaiton
(source: sen2cube.at)

Sen2Cube.at started their initial work for the Austria region in October 2021, then has been evolved into several factbases: Afghanistan, North-Western Syria, and a subset of the Europe region for the SemantiX project (Figure 9). The architecture is adapted from

SIAM software, which automatically categorizes various optical multispectral satellite imageries (Landsat/SPOT/AVHRR/AATRS/QuickBird) into semi-symbolic spectral categories (Baraldi et al., 2018). GUI web-based interaction tool used AI-based expert system under graphical semantic models. The graphical semantic model refers to general and specific expert knowledge (in this case, defined by the user), then transformed as Computer Vision system's a-priori knowledge through semantic query language (Sudmanns et al., 2021). Those models then can be stored in knowledgebase re-used, and transferred to different AOIs and time intervals. From the same study, the semantic EO data cube architect system's general requirement is defined, which ranges from the application support, semantic EO data cube and computing infrastructure, and user interaction and interfaces. Concerning the trend of modern cartography research, the user interaction and interface of Sen2Cube.at system to be focused on. The user interaction and interfaces require: the big data paradigm 'bring user to the data, not data to the user'; web-based program or no installation from the user-side except a standard web browser and internet connection; graphical querying language for abstract data access and algorithm, AI approach for semantic models; Interactive; provide API; provide manual, user support, and facilitate concurrent users with separated space for each.

EO Data Cube Similar Works

An extensive number of research and projects have been using EO data cube technology for delivering EO to a broader audience. Open Data Cube (ODC) is an open-source solution for accessing, managing, and analyzing massive data of GIS - specifically EO data (opendatacube.org). ODC openly collaborates with several international, regional to national institution data architecture solutions, for example, Digital Earth Australia; Africa Regional Data Cube; Swiss Data Cube. The architecture works with Analysis Ready Data (ARD), pre-processed, and ready to use data available on the cloud. Regarding the availability EO data, ODC typically utilize USGS collection 1 Landsat as the demonstration purpose. However, for the vision itself the system is designed to store catalogue large amounts of EO data, Phyton API for access and query the EO data catalogue, provides tool for performing Exploratory Data Analysis (EDA), enables processing large data such as in continent scale, high performance of data quality control and updates. In due to realize those visions, ODC serves a set of open-source tools that can be used by scientists conduct related research, the tools that have been used by the community is listed below:

- **Command Line Tools**: proposed for programmer/developers to interface with the ODC system.
- **Open Data Cube Explorer**: A graphical and interactive web application that allows users to explore stored EO data.
- **Open Data Cube Stats**: A Tool for scientist executing advanced analysis on ODC system.
- **Web User Interface (UI)**: Aimed for developers to interactively showcase and visualize the output of algorithms.
- **Jupyter Notebooks**: phyton algorithm documentation that contains executable code of how the data cube is utilized in a research environment.
- **Open Geospatial Consortium (OGC) Web Services**: non-ODC applications to the ODC system adapter.

The second system that adopting EO data cube technology is Google Earth Engine, where the system serves easy access and analyze multi-petabyte geospatial data catalogue. Earth Engine provides command line tools for the users develop and run their

analysis algorithm. Once an algorithm has been developed, users can produce systematic data products or deploy an interactive application (API) without the ability of application development, web programming, or HTML (Gorelick et al., 2017). Collections of satellite images have the fast filtering and sorting capabilities that makes it accessible for the user to search through millions of images based on specific spatial, temporal, and other criteria. This capability is possible because the satellite images ingested into Earth Engine system are cut into tiles and stored as replica tiles. The system architecture uses a REST API to send interactive or batch of queries from the Earth Engine Code Editor, or third-party applications use client libraries to the system. They also use on-the-fly requests which are handled by Front End servers. Then, the requests will be forwarded to Computer Masters, which is the part of the system that manages computation distributors among a pool of Computer Server. Figure (10) illustrates the simplified version of system architecture.
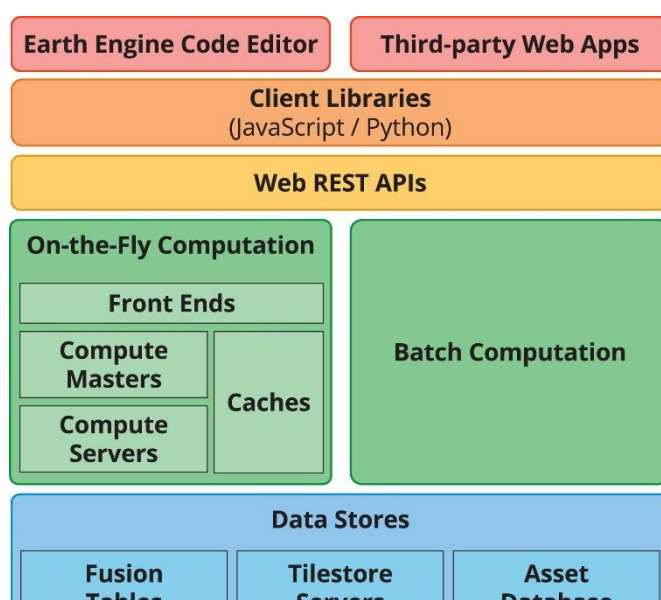
Figure 10. Simplified GEE system architecture
(source: Gorelick,2017)

Through library (JavaScript or Phyton), users can construct queries that range in complexity from simple mathematical functions to machine learning, deep learning, or image processing operator (Gorelick et al., 2017). In other words, the users must at least have programming skills in due to access, query, and analysis the image data collections. Additionally, the operation library stored in the system is allowed to be re-used and modified by the other users who have access permission.

Sentinel-Hub provides access and visualize satellite imagery service. The web application features are available through OGC services and a RESTful API. The platform also provides a web interface named EO Browser, which enables users to access satellite imagery data to be analyzed, visualized, and compared instantly from the web application. Visualization interactive tool of EO Browser allows user to customize the images based on their desired configuration (sentinel-hub.com). The visualization custom works in bands composite by drag and drop into the equation box, modify the strength of the three color channels (gain, gamma, and effect), or customize the Javascript code. Additionally, the JavaScript Custom script also allows to do computation, logical operators, data fusion, or multitemporal scripting. The target user is not declared clear on the website, however concerning the interface and the available functions, this web interface mostly

for beginner to expert level of EO analysis. In addition, there is no official information about how the data is stored and processed.

Compared to the mentioned above projects, Sen2Cube.at web application enriches EO data cube architecture in providing on-the-fly semantic satellite imagery information by interactive Graphical User Interface where does not require programming skill in order to operate the web application. Semantic EO data cubes goes beyond storing data, but further to interoperable building blocks within a data cube (Augustin et al., 2019).

The Copernicus Sentinel-2 Mission

Sentinel-2 mission carries twin polar-orbiting satellites with sun-synchronous orbit monitoring Earth's surface condition for every five days revisit interval. This mission produces satellite imagery for the purpose of benefiting Copernicus services and applications such as land management, agriculture and forestry, disaster control, humanitarian relief operations, risk mapping, and security concerns (sentinel.esa.int). The optical instrument comprises 13 spectral bands with four bands at 10 m spatial resolution, six bands at 20, and three bands at 60 m resolution. The first launch of Sentinel-2A mission was on 23 June 2015 and continued with the Sentinel-2B mission on 7 March 2017. Sentinel-2 products are available free, full, and open access through the sentinel open access hub and via cloud.

Cartographic UI Research

Cartographic interaction has been part of modern cartography discussions for a long time. As MacEachren & Kraak (2001) mentioned in his report, the development of modern cartography is parallel with the development of World Wide Web technology as it has become a prominent medium to disseminate geospatial data. The traditional way audience of the map is an as minimum as read the available information on the map field. Modern cartography deals with the shift of audience action toward web maps through two fundamental keys: interaction and dynamics. Cartographic research nowadays extends to human-computer interaction and enables the dynamic behavior of map objects. Simultaneously, Kraak & Brown (2001) argued that the map has started to play a completely new role: the map is no longer just a communication tool but also a tool to aid the user's visual thinking process. Considering real-time visualization in WWW technology, opens the opportunity to instantaneously change the appearance of the map, which has been we experienced for decades. As was predicted in the same study, high interaction capability in modern cartography develops into manipulating geospatial data, choosing a different type of cartographic presentation, and map visual comparison capability. As a consequence, the study must be accompanied by a deep understanding of UI and UX field in order to support such interaction.

Human-computer interaction in cartography has been utilized by cartography and non-cartography web map service platforms such as Google Map and OpenStreetMap. Over than decades, those web map services have been part of the proof of cartographic tools, which provide interactions to some extent. However, each map service is associated with a slightly different experience of interactivity. A recent study by Horbinski & Cybulski (2020) examined UX of both map services, particularly GUI buttons arrangement, in performing such interactions. Eye-tracking experiment combined with a questionnaire proved to be an effective method to examine GUI efficiency. The result shows that task efficiency performance is guided by the degree of familiarity of users of both map service environments.

Other alternative approaches of cartographic visualization evaluation were described by Sterba et al. (2014). The first method that accommodates usability evaluation is the subjective evaluation of related domain experts or the users of the platform itself. This method allows getting the desired feedback quickly. However, the results highly depend on the choice of the users/experts participating in the assessment. Multi-criterion evaluation method focuses on pre-defined functions, which involves criterion weighting according to their relevance. The criterion possibly includes such as map content, geometric accuracy, visualization, or technical aspects value. This method has the advantage of objectivity. However, the demand for exact specifications of the criterion and lengthy data collection makes this method really time-consuming. The last proposed method focuses on the aesthetic value of the evaluated maps, including all elements and design.

In terms of geovisualization tool design research, Anthony et al. (2005) took a study on geovisualization tools for an Epidemiology project (Figure 11). The designing user-centered tool is the main focus of this study, which incorporates user participation through all six stages of the creation process. Several types of assessments that are applied are interviews, focus group discussions, and informal assessment activities. The work reported massive efforts of loop evaluation as the effect of including user participation through all stages, which is obviously time-consuming. Therefore, this approach is more suited to a long-term project. Nevertheless, the workflow is beneficial for creating an agile system.
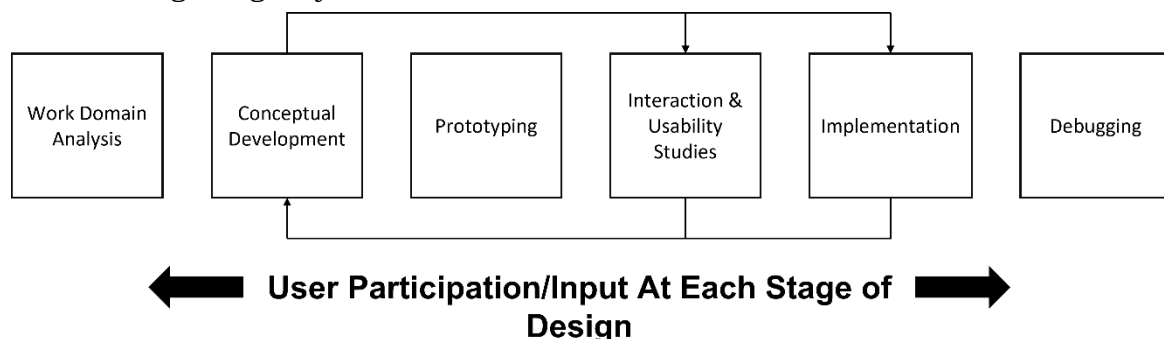

Figure 11. Geovisualization User-Centered design process (source: Anthony et. al,2015 with modification)

Work domain analysis as the first initial work represents the communication of proposed ideas and requirements between the developer team and the client. Epidemiology experts interview were also performed in order to provide detailed information about epidemiologists and the work scope. *Conceptual development* is defining the core of the application, including the desired features that might be included. The layout, tools, and application architecture are designed as a graphical concept prototype. Iteration of redesigning the prototype is through regular meetings. *Prototyping is* essentially concurrent with *Interaction/usability studies* which are crucial for understanding the desired features and assessing the functionality. There are two types of assessment that are applied in this study: formal assessment through recorded user testing, interviews, and focus group discussion. The second type is a wide range of informal assessment activities as the system is critiqued internally. Afterward, the *Implementation* stage begins, typically revealing design issues. The note from the study that during this process, it is difficult to simulate real work in order to ensure there are

no significant problems during implementation is running. Then, feedback loops are initiated to tackle this problem. Therefore, any problem issue will be immediately solved through conceptual development and interaction/usability studies. *Debugging* is the final stage of this whole geovisualization tool. The running application is adjusted to enhance stability and compatibility. In this part, the adjustment mostly worked on the computing infrastructure of the application.

Given the experiment of user evaluation for Citizen science websites, Newman et al. (2010) observed a guideline for developing web mapping applications. This study emphasized (1) integration between user feedback and usability into web mapping application design and (2) creating features based on user needs, supporting various user group roles, and controlling data quality. Involving users in the design of web applications will be improved. Despite the documented guidelines, this study also discovered that between participants of user evaluation would like to communicate with each other, collect, contribute, and 'publish' their own data on the internet. Table 2 below is several guidelines that can be used for web map applications in general.

Table 2 Guideline for developing web mapping applications

Communicate the purpose of the website and user roles
Build features for both project managers and users and clearly separate them
Develop customizable data entry forms and ensure the data quality but remains simple
Create simple map applications that visualize accuracy, precision, and uncertainty
Add spatial literacy learning
Provide information to help map interpretation
Incorporate with help page for providing spatial concept understanding
Allow users to experiment through beta testing
Create features to map attributes and visualize the accuracy
Create an online questionnaire to better integrate user feedback, participation, and program evaluation

4 SEN2CUBE.AT SYSTEM EVALUATION

4.1 Sen2Cube.at System User Flow

With the rising number of active users, improving the image map visualization has become an emerging step toward enhancing the web application user experience. Instead, continuing in any spatial desktop software to refine the image map result, to do it in the same environment as the analysis process goes, will be a plus value of Sen2Cube.at. User evaluation assessment could be a solution to understand the user needs, particularly in the image visualization aspect. This assessment will be a preliminary work to develop a prototype visualization tool in Sen2Cube.at system. On that account, this tool will meet user needs to support their work.

In order to create an inference of image analysis, the user follows a certain User Flow. User Flow in the UX field is a diagram that illustrates the complete path taken by the user when using the web application. Starting from the entry point, perform the task until complete the task. User flow has a different name, such as UX flow or flowchart. In this study, we will use the term user flow. User flow helps to understand and anticipate the cognitive pattern of the users for completing actions through the site (Browne, 2019). In Sen2Cube.at web application, user entry is by login into their personal account as the first webpage landing. Continue to the main webpage, where there are various tasks that they can perform. In this study, we focus on the main task: inferring spatial information. To create an inference product as an image map or statistics diagram, the user must follow certain user flow as illustrated in figure (12 & 13) below.

The first action on this task is selecting a model which allows users to choose or make their own model by building blocks to determine the entity that they would extract from the available Sentinel-2 imageries dataset. Through the model block, the user also determines the product of inference, such as an image map or statistics graph. In this study, we use the study case of image map inference. Then users can move to the next action in the Factbase menu where AOI and interval time of interest are quired. There are two options for creating AOI: draw directly on the map and use the GeoJSON dataset. Both can be combined if the user has more than one AOI. The time interval is determined by choosing the start date and end date period of interest. The inference menu only includes a button for executing the inference process and the open inference history of the user. Additionally, the user also can choose how the image map will be visualized: View mode or Quick preview. View mode shows the image map with its original spatial resolution either Quick preview degraded the spatial resolution due to reducing processing time.
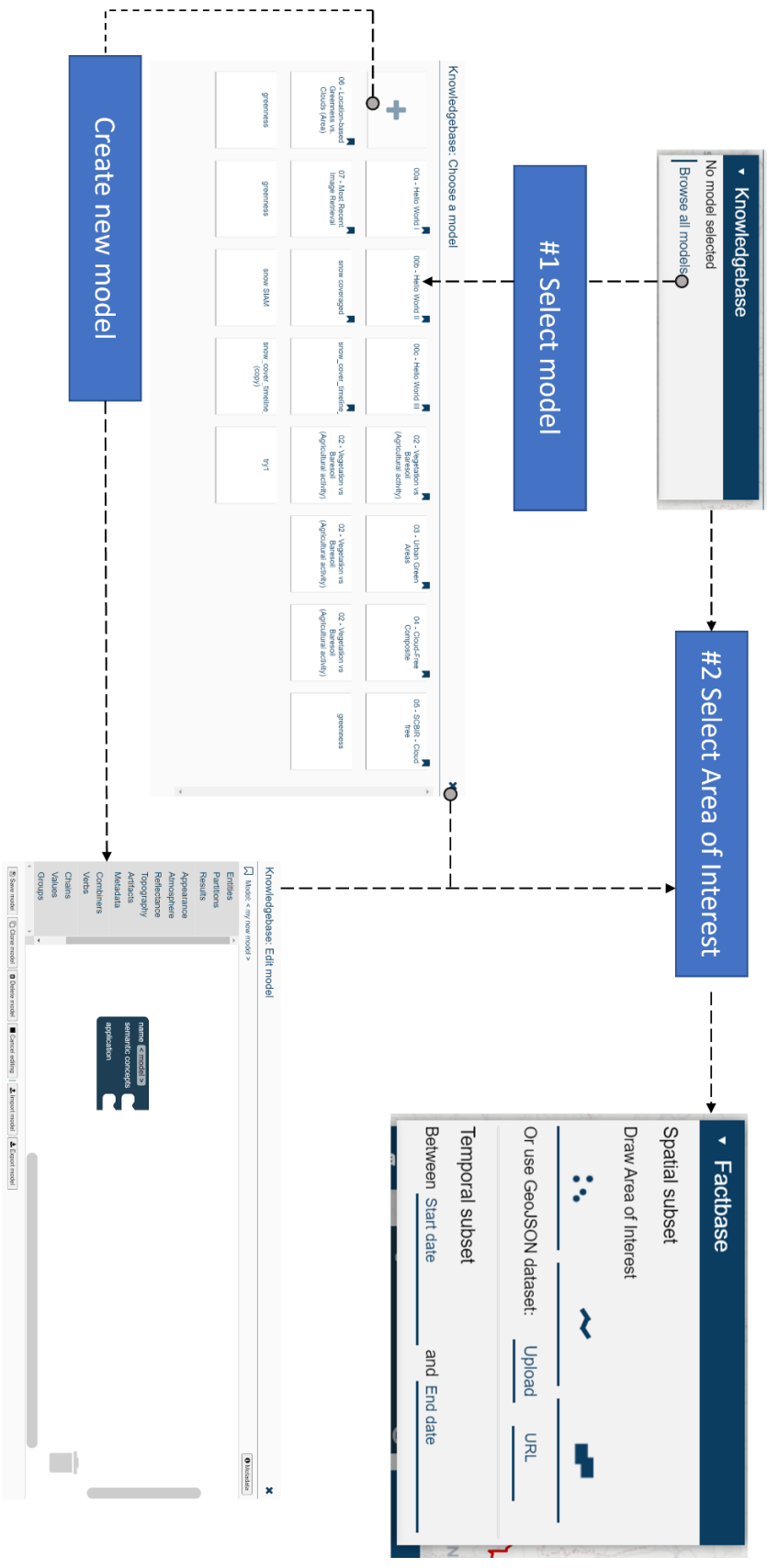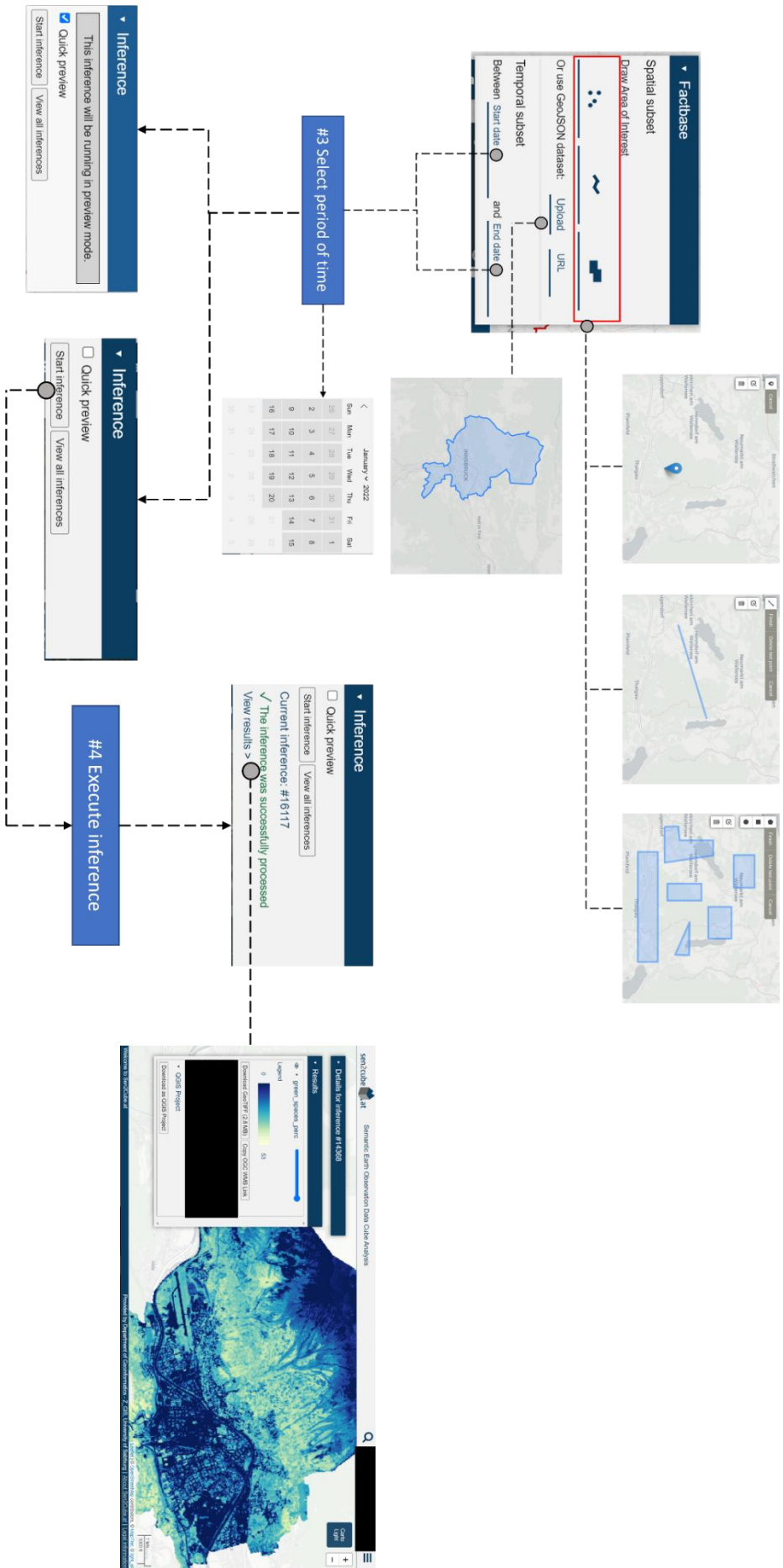
Figure 12. User Flow

Figure 13. User Flow

4.2 SWOT Analysis

SWOT analysis is an approach to determining the strength, weaknesses, opportunities, and threat keys of the system. SWOT analysis is extracted from system examination from both sides: Sen2Cube.at developer team under formal/informal discussion and user's feedback through questionnaire and in-depth interview. Sen2Cube.at as a web application assure 'on the fly' semantic inference of Sentinel-2 imageries with the flexibility for the users to define the analysis model block. The product of inference is available in two dimension data: time and space. Time dimensional data is presented as a chart graph which allows the user to do further statistical analysis. Space dimensional data is visualized as a semantic image map that could be downloaded into the user's own system. However, in due to creating a preference inference model block takes quite a takes time. Default symbology of the image map result takes most concern from the user evaluation participants, they also mentioned that the opportunity to have the flexibility to modify the symbology would be a great improvement cartographic aspect of the system. The threat that is found in the recent condition is the instability of server performance during a certain time period. The SWOT analysis is summarized in figure (14). In this study we focus on the visualization aspect of Sen2Cube.at that the potential to be improved. However, other potential improvements that are outside of the study scope are also presented in the table below.

STRENGTH	WEAKNESS
• Query and process sentinel imagery 'on the fly' • Temporal analysis • Model builder • Three types of raster map products: GeoTIFF, QGIS Project, WMS link • Chart graph as inference product	• Taking time to understand model builder • Preview mode in color default • Chart graph quite hard to comprehend • Downloaded image in GeoTIFF must be processed to GIS/RS software to have convenient visualization
OPPORTUNITY	THREAT
• Flexibility for users to modify the map result both layout and symbology • Additional zoom capability to the extent of AOI • Filtering chart graph based on selected AOI	• Server performances

Figure 14. SWOT analysis result

4.3 User Evaluation

User evaluation is held under two versions: questionnaire and in-depth interview. The questionnaire is aimed to understand the general need of users, particularly in visualization capabilities improvement, followed by an in-depth interview to get the specific needs of core users. A short digital questionnaire that spread among active users consists of three sub-topics within 16 questions in total, with each question having a unique identification code (look at attachment 7). The first sub-topic focuses on user

background, particularly in education and expertise. The second and third parts focus on the usability UX evaluation.

From user background information, it is recorded that most users of Sen2Cube have been at least intermediate to expert knowledge in Geoinformatics (GIS or RS domain) with a year of expertise between 2 – 5 years. This means users have a prior understanding of EO analysis which is linear with the group target of Sen2Cube.at website. The second sub-topic questions are divided into two concerns of UX evaluation: goal of web map use and map visualization aspect in the web application. There are three main purposes for using Sen2Cube.at from 15 responses in total (question ID: UE02). Almost half of the respondents use Sen2Cube.at as a tool for query polygon location-based for time series analysis and entity-based spatial analysis. A high percentage of semantic content-based image retrieval also shows as the third majority purpose. Additionally, two of the respondents mentioned their current work building Sen2Cube.at the tool in the ArcGIS environment (Figure 15).
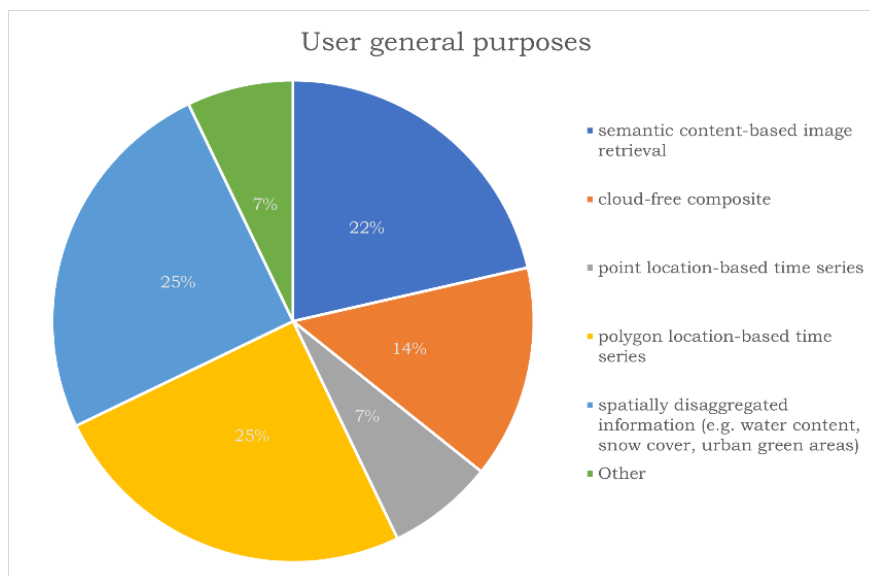

Figure 15. Sen2Cube.at user general purposes diagram pie

The second UX evaluation sub-topic, including both GUI previewing image map and the image map visualization is examined based below statements. The majority of the users are satisfied with both GUI and the image map result (Figure 16). The window bar position and the sequence is fulfilling the intuitive aspect of the map web application. However, more than half of the respondents need further image map modification on other software. This statement then is supported by the result of the last three questions of the same sub-topic. The last three questions focus on the common pattern of image map utilization. Sen2Cube.at provides three options of image map related-action besides visualizing directly on the web application. Users can download the result as either GeoTIFF or QGIS project. Additionally, users also have the flexibility to embed the result in their own web in WMS format. 63% of users usually download the image map and continue to analyze or adjust the visualization through RS/GIS software (figure 17). Users also mentioned their difficulty in analyzing the result as a series of image maps (multiple bands), which in Sen2Cube.at system will only display one of the available bands. Therefore, the majority of users need other spatial or statistics software as the last step

of their satellite imagery analysis. Respondents mostly use software such as ArcGISPro and QGIS for further modification, and data analysis software such as Tableau, R, and Jupyter Notebook are highlighted. Nevertheless, 21% of users agree that the web image map is adequate for a quick check of the inference.
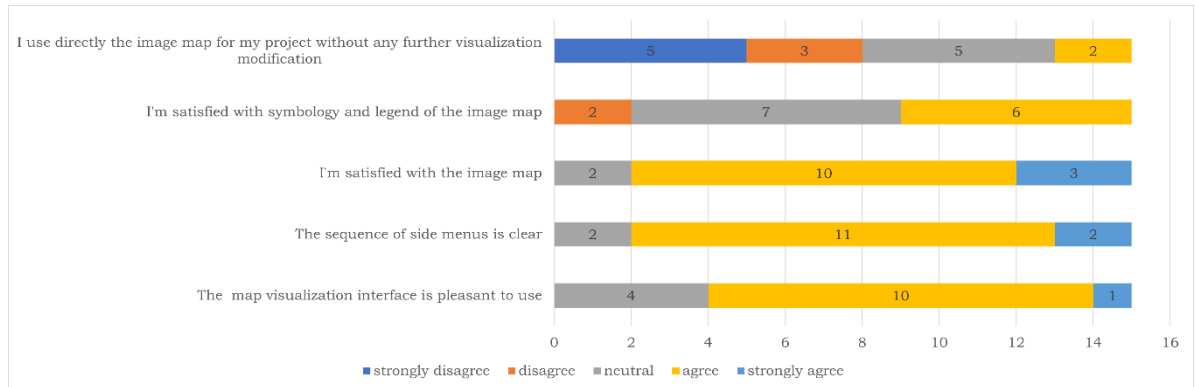

Figure 16. Questionnaire result regarding the satisfaction of GUI and the image map result

An additional question is displayed when the users complete their analysis, including visualization modification. The map elements that commonly add to the final image map are displayed in figure 18. Half of the respondents need legend and scale element for their map, followed by title and supporting vector layers. An Interesting finding, users are most likely to add additional text rather than basemap to the final image map. A highlight from that result, it is important for them to have some brief explanation of the legend value in case to disseminate the image map to a broader audience.
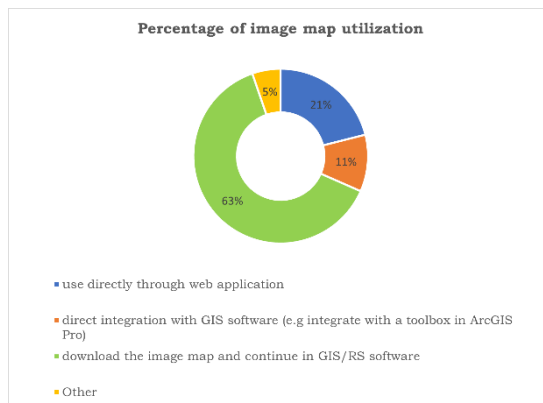

Figure 17. Questionnaire result of image map utilization
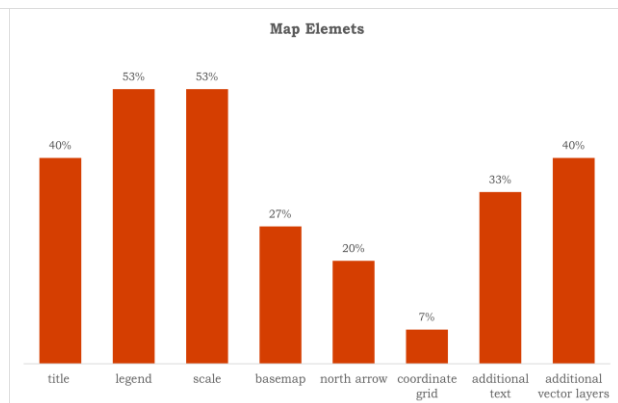
Figure 18. Questionnaire result of common map elements to be added

The last sub-topic took a specific inference model as the example case for visualization improvement concept design. A window of urban greenness percentage model is attached (figure 19) in order to user examines the recent visualization capability of Sen2Cube.at and determine the thresholds. Therefore, open question type is chosen. Then the analysis focus on keywords that appears based on the collected responses. By the end of this last part, general feedback is also provided as an open answer box, which almost all the respondents filled.
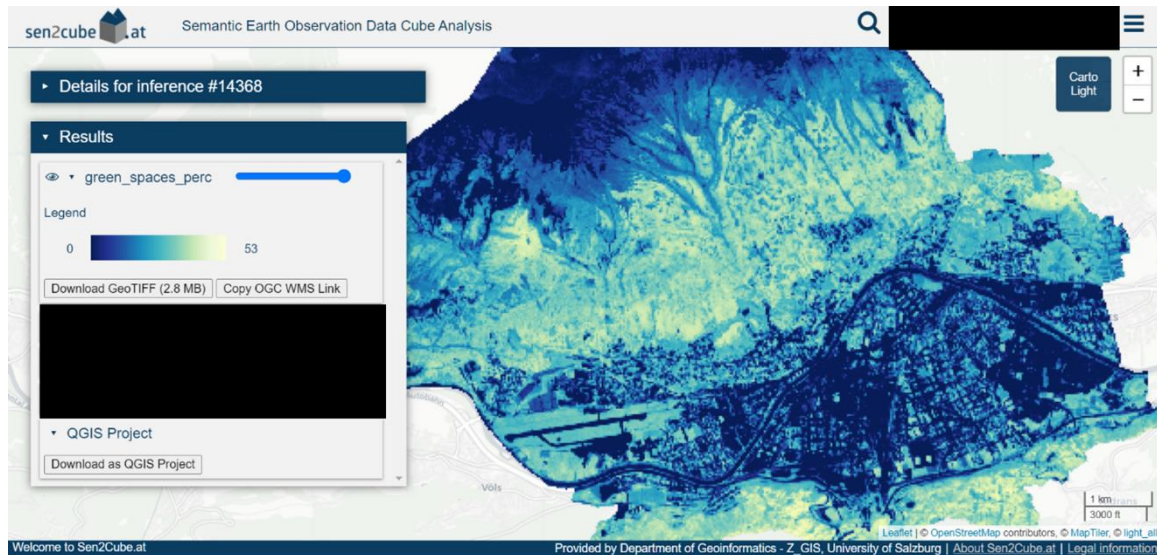

Figure 19. Example of image map inference product

The first part of this sub-topic examines illustrated image map. Many respondents agree that both legend and symbology represent the data. However, in the explanation box, 8 participants mentioned that both color coding and value are not matched. They further explain that the darker hue should represent high value, and green color coding would be a better choice to represent the greenness percentage. Furthermore, the data value classification is also perceived as another issue, which they prefer to percentage as classes rather than continuous type. This result is also supported by the answers from future interaction tools in Sen2Cube.at which 80% of participants admit new tool symbology and legend widget would be an alternative solution. This tool will allow the user to customize the symbology color and the data value accordingly. Another possibility is the cartographic element widget which allows them to add and remove map elements. Regarding this matter, a similar question with the second sub-topic is added, and the result resonates similar proportion, which legend and scale elements are the most preferred. However, a contradictory result is shown between question ID UE07 and MV03 (look at attachment 7). In this part, the number of users that would likely add basemap exceeds users who choose to add additional text (figure 20). The last preferred visualization tool is measurement tools, a tool for distance or area calculation from spatial subset input.
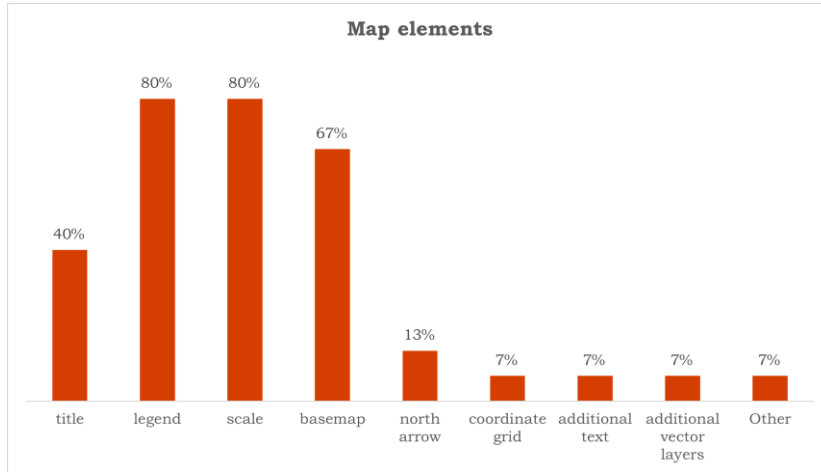
Figure 20. Percentage of desired map elements from question ID number MV03
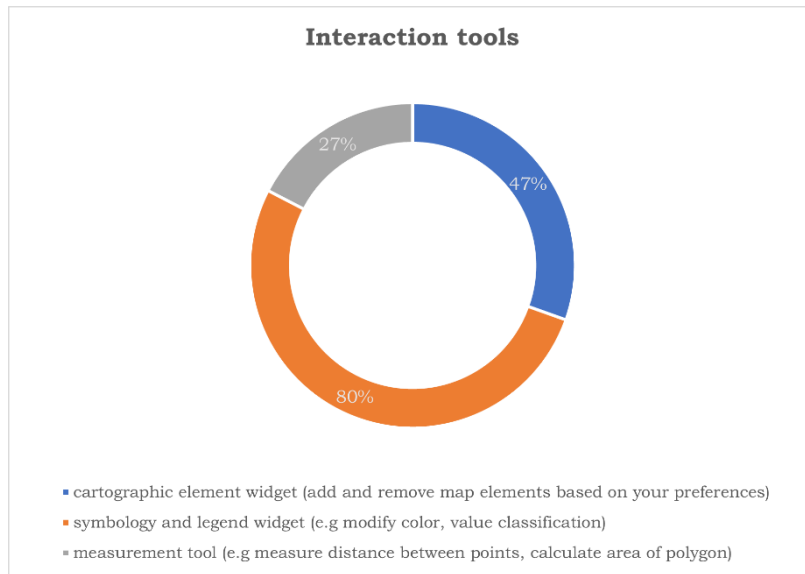

Figure 21. Percentage of preferred visualization tool

An in-depth interview is performed as the latest part of the user evaluation stage. The interview is conducted to discover the specific problem of UI from core users. Good-Turing and Normalization procedure is applied as the combination of both is the best practice in small samples for adjusting initial estimates of problem occurrence in usability study (Lewis, 2001) by using MeasuringU web application. In this study, we discovered 85% of all problems mentioned in the questionnaire result. This percentage is the threshold for creating a matrix of the problems encountered by all users (table 3). Five main issues are formed from questionnaire question lists (table 4). The categories refer to the general issue of visualization aspect. The five problem categories consist of manual webpage satisfaction; current symbology and legend; layout and map elements; visualization modification; UI satisfaction. The value of the matrix is filled by 1 or 0. Value 1 refers to the user encountered the problem, and 0 means the user does not consider it

as a problem. The matrix of 15 participants--five problems shows the average value of Normalization is 0.44 and Good-Turning value is 0.54, and the adjusted problem occurrence is 0.48, thus the recommended sample size of the total participants is three participants to be interviewed.

Table 3 Matrix Participant—Five problems

User ID	manual webpage satisfaction	current symbology and legend	layout and map elements	visualization modification	UI satisfaction
16				1	1
18		1		1	1
20	1	1		1	
21	1	1		1	
23		1	1	1	
26				1	1
27				1	1
28		1		1	
30		1	1	1	1
31			1	1	1
35				1	1
38		1	1	1	
40		1	1	1	

The in-depth interview comprised three parts: usability and efficiency evaluation tasks, post-discussion, and discussion relating to the visualization improvement. In the first part, users are asked to perform two preserved inference models to examine the current usability and efficiency of Sen2Cube.at in order to produce an image map along with several questions by the end of each task accordingly. Post-discussion focuses on the visualization improvement that can potentially be applied in Sen2Cube.at by reflecting on the completed tasks. In this part, several EO web applications are involved in order to gain insight into how the visualization tools might be. The last part of the interview aims to gain the visualization threshold by evaluating several image maps prototypes from the previous questionnaire.

table 4 Five encountered problems

manual webpage satisfaction	current symbology and legend	layout and map elements	visualization modification	UI satisfaction
UE03	UE04-SQ004	UE04-SQ003	UE04SQ37262	UE04SQ001
	MV01	UE07	UE05	UE04SQ002
	MV02	MV05	UE06	MV02
	MV05	MV04-SQ001	MV04-SQ002,SQ003,SQ004	
		MV03	MV05	

The first and second parts of the interview emerged several problems encountered by the participants. They had difficulty drawing the AOI polygons when they were asked to draw two polygons (first task) and three polygons (second task). When creating one polygon and moving to the next polygon, the web application only works if the button for

creating polygon is in off mode. Instead, participants mostly automatically move around the map by press and hold their mouse button. Additionally, participants mentioned the spatial subset that they usually do is by upload the GeoJSON format data instead use the drawing tool. Nevertheless, the 'Search' and changing basemap are utilized perfectly by the users for finding the intended region as mentioned in the task instruction. Besides spatial subset, both tasks also require temporal subset on a certain time period by defining the 'Start date' and 'End date'. This feature was not quite intuitive to participants due to selecting time, the system is not automatically showing the same year on 'End date' as the selected year in 'Start date'. Another remark is changing the inference model from the first task to the second, they had mistakenly clicked on the selected inference model rather than 'Browse all models'. The QnA session afterward was focused on how the symbology and legend represent the information by raising map interpretation. All participants showed the capability of GIS professionals how to interpret the information through map. However, all of them alert the concern about the misleading color ramp of high value and low-value entities, for example in the first task, the result of inference product is two image maps: vegetation area in percentage and baresoil area both are in continuous percentage value with dark blue to yellow ramp color. The dark blue represents low percentage of the entity, and bright yellow for the high percentage. According to the participant's feedback, they intentionally assume that the dark blue area on the map is high percentage, and they also alert the symbology does not represent the color of the object in the real world. Furthermore, they emphasize data classification is not suit for such data as they prefer discrete rather than continuous.

The last part of the in-depth interview addresses the visualization improvement by referring to the mapping web application and image map prototype from the previous questionnaire. As the questionnaire result shows that 80% of total participants agree to have symbology and legend widget that allows them to modify the image map visualization, and the second desired tool is the cartographic elements widget that allows to add/remove map elements on image map product. There is three mapping web application that was compared for visualization tools: ColorBrewer2.0, landcover.io, and EO Browser Sentinel-Hub (figure 22). Three of mentioned web apps have a different ways of visualizing map. Colorbrewer2.0 is known for color advice for mapping, which provides the interaction of selecting a color scheme based on the nature of data according to the cartography color principle. The second web application is similar to Sen2Cube.at which provides land cover inference extracted from satellite imagery. This mapping app has 'refine result' window, which allows users to modify the symbology of each land cover class by the color picker window. The last web app is EO Browser Sentinel-Hub provides 'Visualize' window that allows users to modify imagery attributes on-the-fly by selecting pre-installed spectral band combination, sampling method, and effect use sliders icon. All participants agreed that colorbrewer2.org is the most suitable way of how the symbology and legend tool should be applied, since most of the cases of their projects need quick visualization. Next, an examination of map prototypes is performed to discuss the desired concept of the cartographic map elements tool.
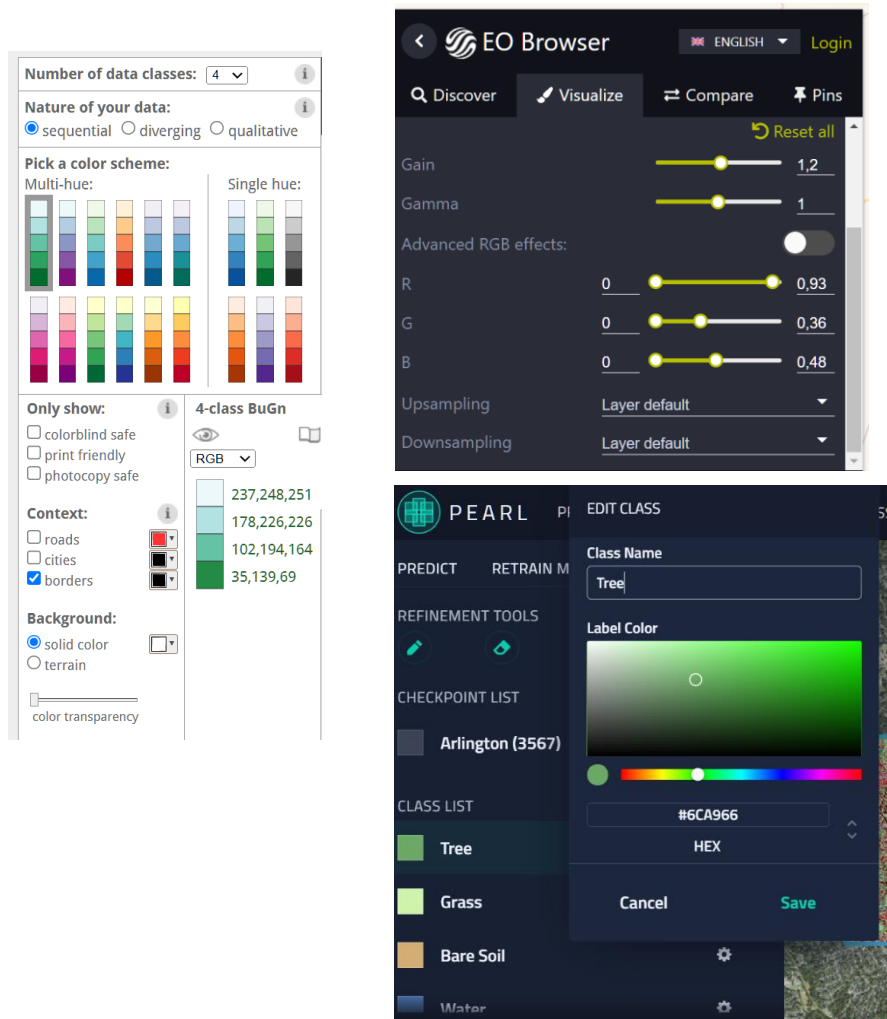
Figure 22. ColorBrewer2.0 (left), EO Browser Sentinel-Hub(right-above), landcover.oi(right-below)

Three image maps from the previous questionnaire are shown, including map elements (title, legend, scale, basemap) with different types of legend. Additionally, one image map from Sentinel-hub.com as they also provide the download imagery map with modified symbology. All participants choose a map with a discrete legend because easier for them to distinguish the data value. They did not find any problem with the scale line as default. However, for the title element, they insist to allows for editing rather than automatically generated. Therefore, text edit tools might be a potential solution in the cartographic map elements widget. Regarding the basemap, within the current options in Sen2Cube.at system is enough for them to give their image map a context. However additional hillshade layer is also suggested.

4.4 Formulating Sen2Cube.at Visualization Guidelines

Results from the questionnaire and in-depth interview are then formulated as visualization capabilities thresholds. There are two aspects of image map visualization that potentially be improved: map layout and visualization tools. Map layout includes map elements that are necessarily needed by the users, and visualization tools refer to interactive tools for modifying symbology and legend. In this manner, a certain scenario of user workflow is used to define visualization capabilities thresholds. The scenario

starts from users in the result window as their final inference product without refinement. What they need to do next is visualize the image map and download it to their own local storage. In order to accomplish this task, a map layout format guideline is formed with specification map elements that follow cartography rules and principles of the image map product. In order to accommodate the principle of map layout, two formats of map orientation are provided (landscape and portrait). Those layouts are specified based on the shape of AOI (figure 23).
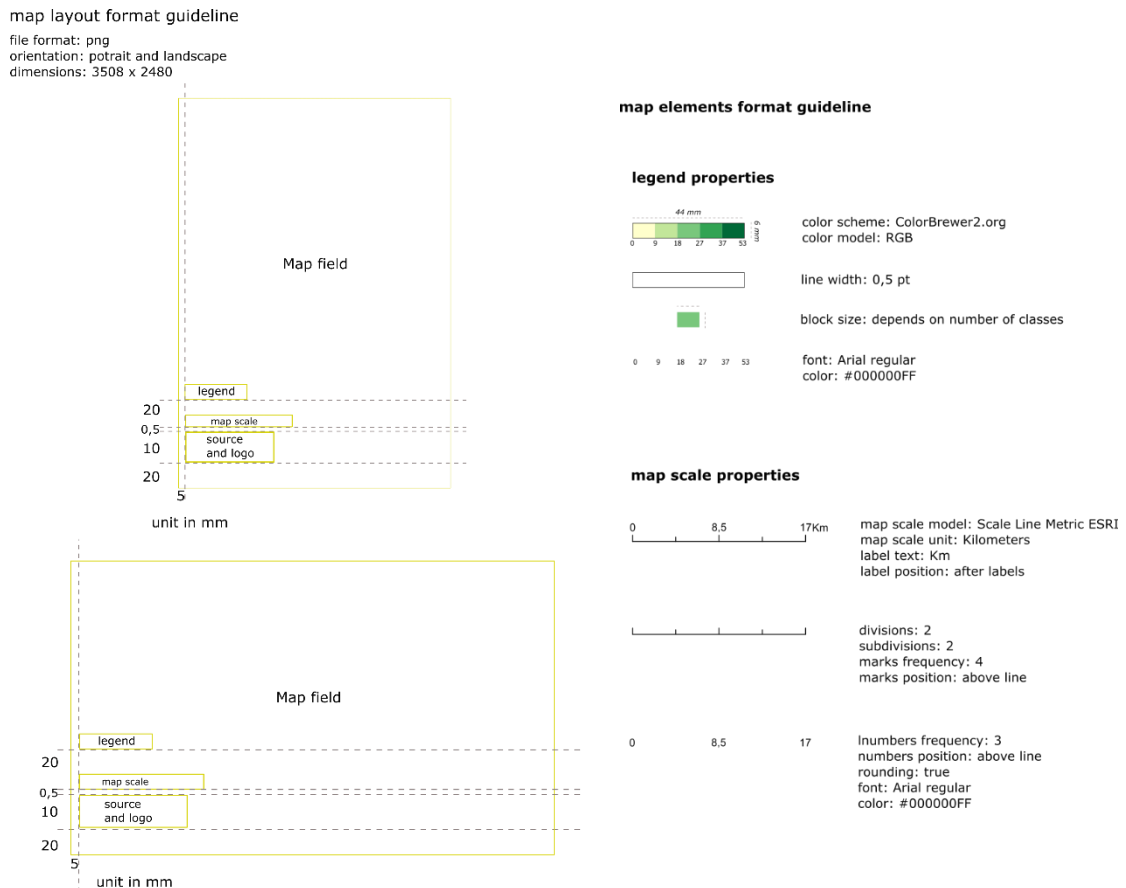

Figure 23. Map layout guideline (left) and map elements guideline (right)

Based on the questionnaire and in-depth interview results, there are three map elements that are important to users to be shown in image maps: legend, scale, and basemap. However, participants would like the possibility to add title to the image map with the flexibility to edit rather than automatically generate from the inference model name. Additionally, the default text of the source and logo of Sen2Cube.at at the bottom of the image map is accepted by all participants. The position of element maps is placed according to cognitive cartography principles as human eye intuition starts to screen the map from the up-left to down-left side. Certain padding between element map positions is also specified in the map layout guideline. Both legend and scale properties are also defined in the map elements guideline. Addressing map layout concerns is also performed under the cartographic elements widget as an interaction tool to add or remove preferred map elements, as 47% of the total participants chose this to be applied in Sen2Cube.at web application. Based on those defined thresholds together with the model inferences results, a set of model image maps are created to visualize those concepts. The image

map models are produced based on the model inferences (water percentage model and vegetation v.s. baresoil model) that had been examined during both questionnaire and in-depth interview sessions (figure 24 & figure 24).
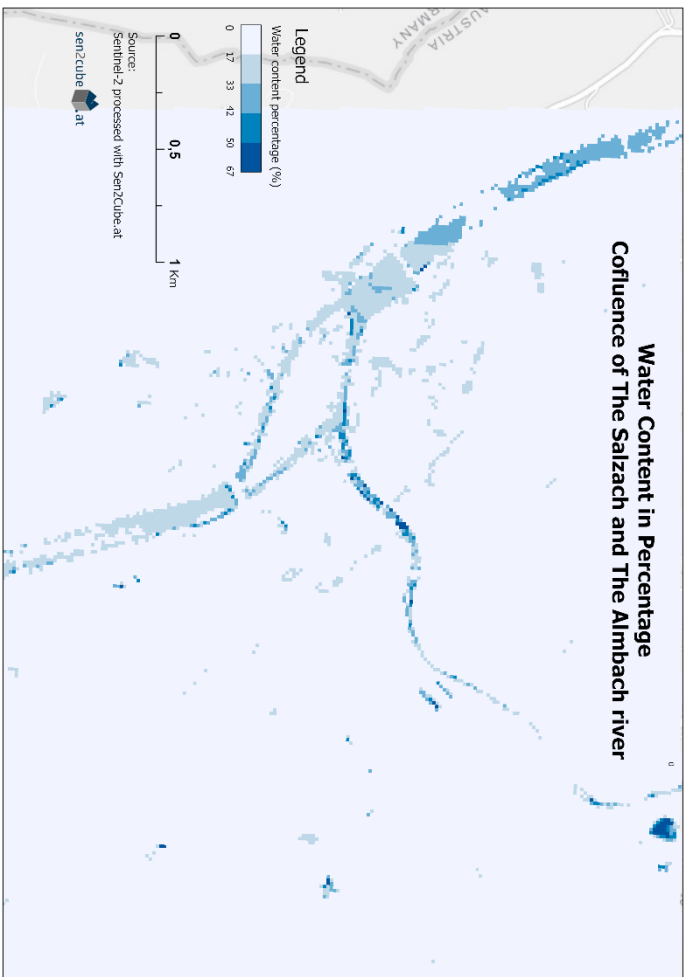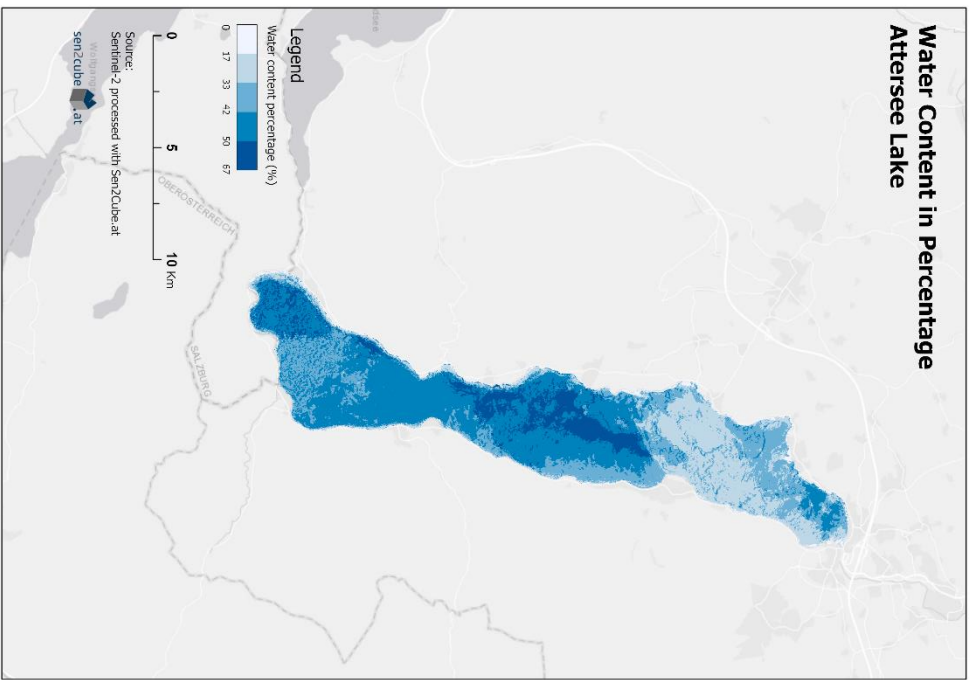
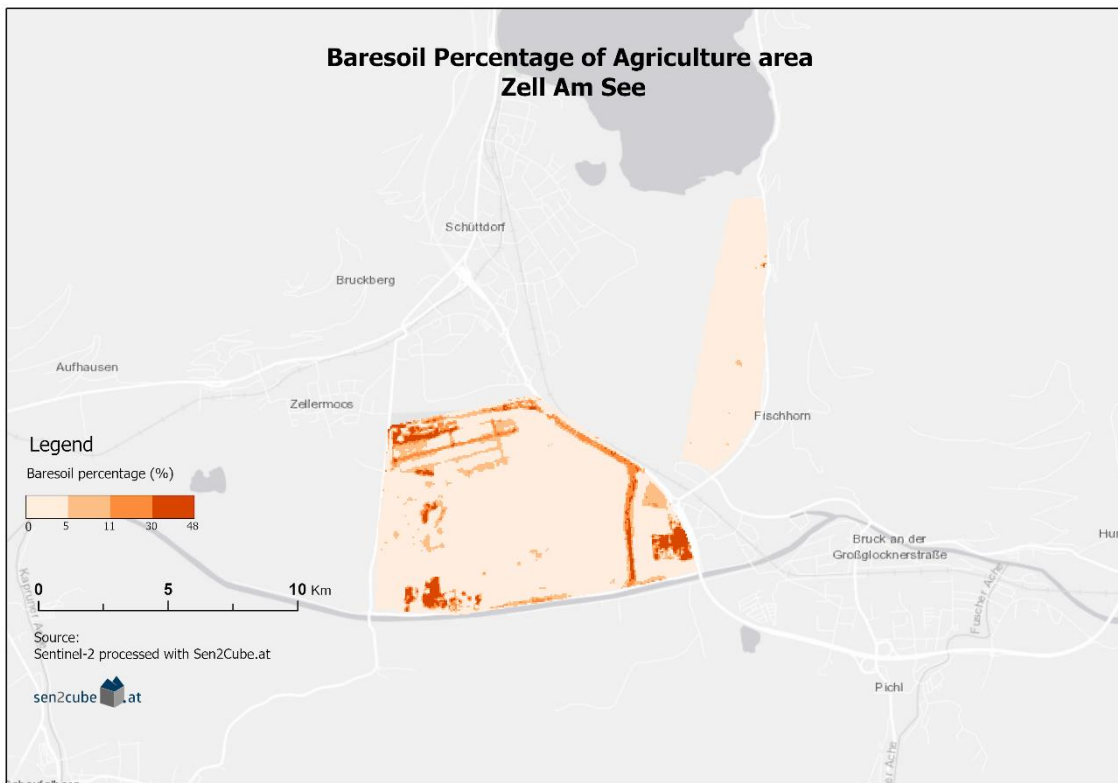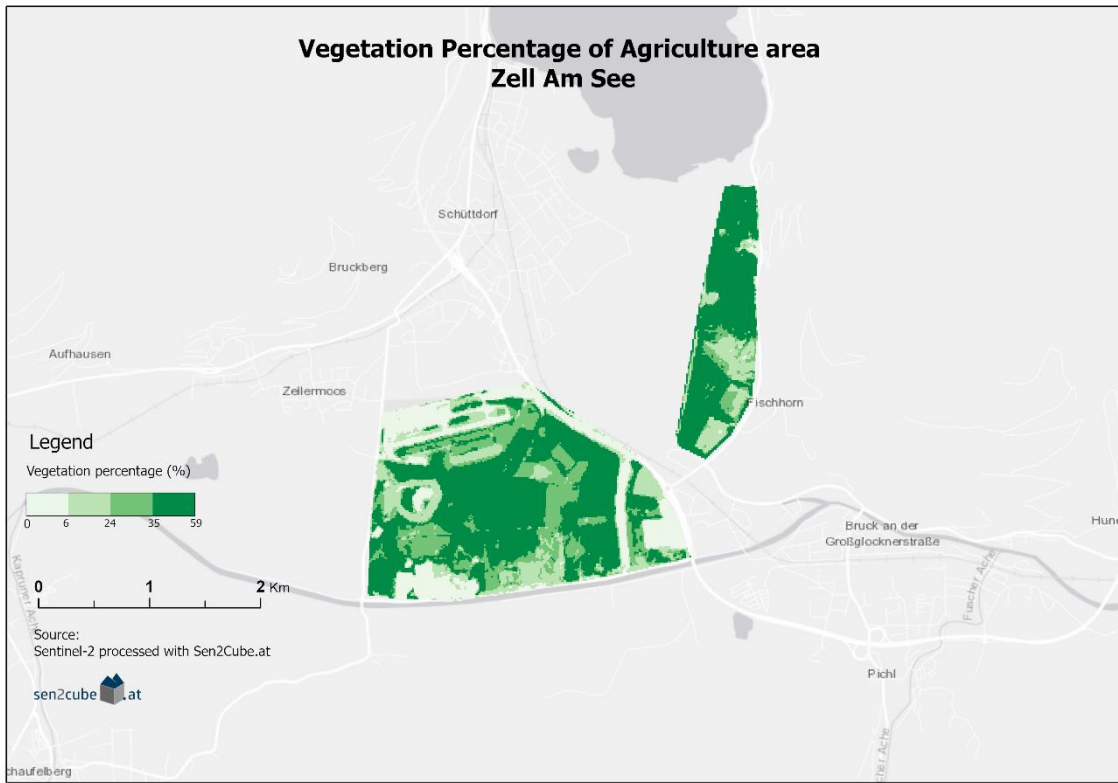**Figure 24. Water content image map model**

Figure 25. Vegetation (above) and Baresoil (below) image map model

5   DESIGNING VISUALIZATION TOOLS

5.1 Visualization Tools Wireframe

After defining the thresholds of visualization capabilities, a prototype of the intended visualization tools through UI wireframe design is created. Wireframe in UI design is a critical step for creating a User-Centered Design process to accommodate user's tasks when they use the web application. Wireframe also helps ensure the tools and functions are positioned correctly and provides an early visual of how the web application looks with the additional functionality. In order to create a wireframe, a certain user task flow must be defined as the framework. Based on previous user evaluation, most users follow the below task flow (figure 26), then the visualization function potentially takes place between 'viewing the result' and 'downloading the image map' section.
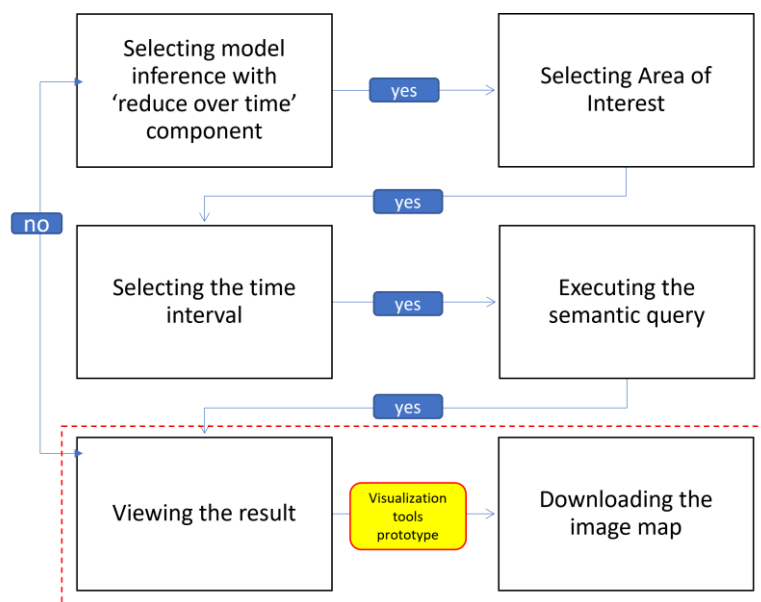

Figure 26. Scenario of task flow

The new workflow runs on the view result web page, starting by examining the result. If they are satisfied, they could continue using the visualization tools, or if they need to improve the result, they can go back to starting point. Selecting a layer becomes the next step since the inference model might produce several image map layers. Therefore symbology could be specified to the entity that is visualized by each layer. Modifying symbology also includes an option to classify the value, which might be done using the Natural Jenks algorithm. Based on the number of classes input, the legend is then generated using ColorBrewer2.0 color schemes library. ColorBrewer2.0 provides its master color scheme format in CSS, which can be applied to any web application. Optionally, the d3js library of ColorBrewer is also available both for continuous and discrete schemes.
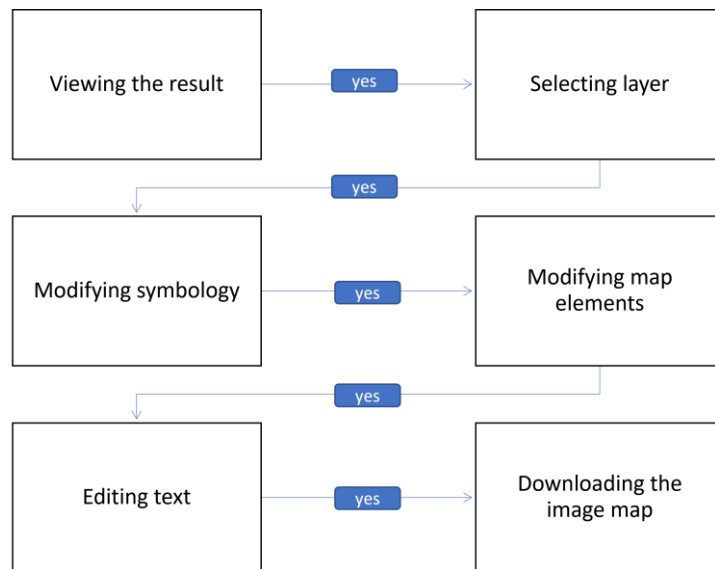
Figure 27. Task flow for creating wireframe

Afterward, users could continue to modify the map elements based on their preferences. By default, the map elements include scale, legend, and basemap. Map scale might best follow the OGC zoom levels for web map format. The legend automatically refers to the previously modified symbology and the basemap depending on the current use. The editing text tool is a potential solution for adding text such as title and short text that might be needed. The text editor as box format will suit this function due to the flexibility to move around the text into the body of the map layout. Once click this tool, the map layout automatically could be generated, thus a trigger task for downloading the image map in PNG format. PNG format is chosen because this format accommodates better resolution rather than JPEG. The option for downloading in GeoTIFF format is also available as the solution for users who want to use the image map to further analysis which also eliminates the map elements.

The wireframing process starts by creating a sketch of UI design on paper as Low Fidelity wireframe type. A rough design of the UI is created first because any modification can be done quickly. This paper wireframe was then transferred into High Fidelity Wireframe to showcase the interaction on the web application. Figma UI design software is chosen to execute this final step of prototyping. Figma allows one project free to any UI/UX project. Furthermore, Figma also provides the CSS code for each feature that has been created through the design process. Due to presenting the interaction functionality on the UI, Figma provides a clickable prototype based on the task flow that we created before. In this study, we use wireframe flow in figure (27) as a framework for how the visualization tools can be used. There is a new menu window called 'Visualization' below the 'Result' menu window where the visualization tools are placed. Both symbology and cartographic element widgets are accommodated in this new menu window (figure 28). The placement of the feature chronologically follows the intended task flow. Therefore the intuitive aspect as the part of the interaction function is applied here.
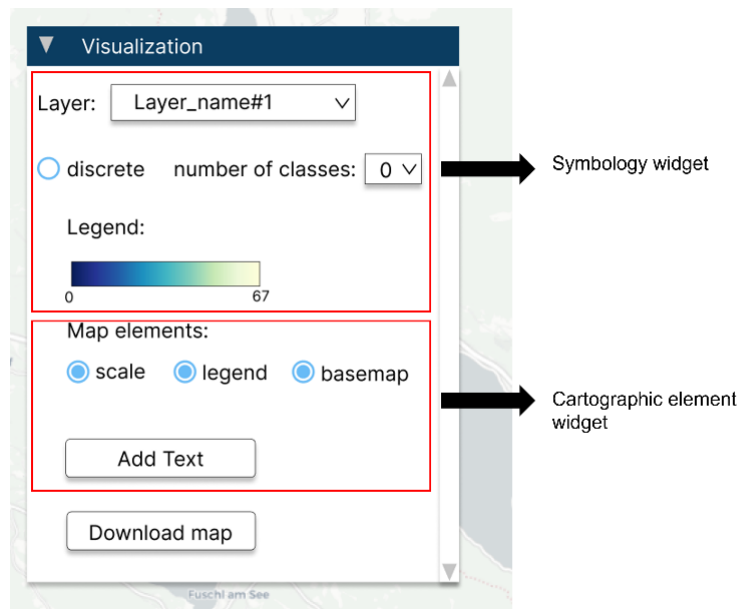
44

Figure 28. Visualization menu window

5.2 Symbology Tool Concept

Concerning the result of both questionnaire and in-depth interview, 80% of total participants believe that symbology and legend widget is one of the potential improvements in Sen2Cube.at web application. Therefore, such feedback is then applied under the symbology tool concept. The principle of this improvement is allowing the users to have the flexibility to modify the image map visualization based on their preference with ColorBrewer2.0 color scheme model. In this subchapter, we try to elaborate on the potential concept of developing a symbology tool. There are three main buttons in the symbology tool: Layer, Data type, and Legend button (figure 29).
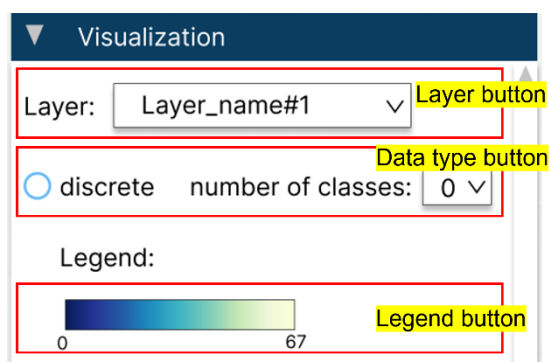

Figure 29. Symbology widget

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Layer tool allows users to select the image map layer that they would like to modify, concerning the data type of entity, option for transforming it into discrete data type is added together with the number of classes option. After the data type is defined, the color symbology could be modified. ColorBrewer color scheme is applied here as the majority of user evaluation participants chose such web as the visualization tool reference. Once the color ramp is clicked, the options of color schemes are shown (figure 30).
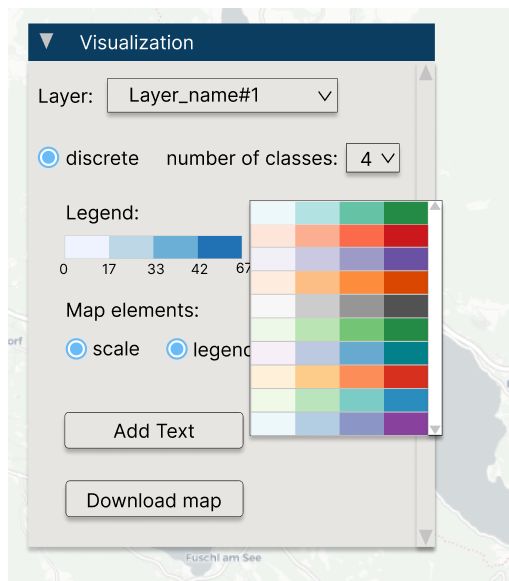

Figure 30. UI once the color ramp is clicked

Based on ColorBrewer, there are two types of hue intensity: multi-hue and single hue. Hue in color theory represents the dominant color family, multi-hue means there is two opposite color in one color ramp. This scheme suits for different intensities of two opposite entities instead of the single hue fit for representing the intensity of one entity. In this task flow, we use the water percentage model as an example. For this prototype purpose, we use the d3js library as the color scheme reference. On the official web page of the library, they provide the SVG file for all the color schemes generated from the color code of ColorBrewer2.0 color scheme (figure 31).
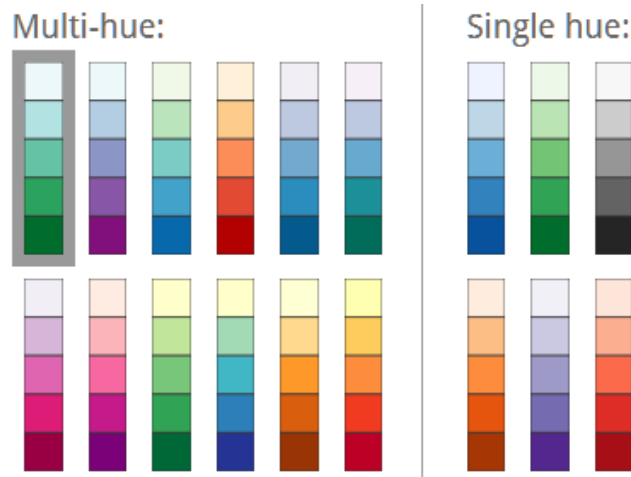
Figure 29. ColorBrewer2.0 Color schemes

5.3 Cartographic Element Tool Concept

The second potential visualization tool is the cartographic element widget which provides interaction of choosing the map element that might be added to the image map product (figure 32). According to the user evaluation, legend, scale, and basemap are the top three the most voted. Those three map elements then are designed in map element guidelines as described in the previous subchapter. Generally, the concept of those map elements could be added or removed by clicking the on/off button. However, by default, three of those are turned on. In case of basemap layers availability, the additional hillshade basemap is added as a result of user feedback, hillshade layer is necessary to give the image map a geographical context.

Figure 30. Cartography widget

Add Text button is designed differently from the rest of the cartographic element tool because of user preference. They have different options such as title text, text about the data value, or additional short text data explanation. In order to address this issue, a classic text editor is chosen. The text editor button allows users to add more than one text box and placement flexibility to the map layout. The text editor box might have the interaction of font editing properties such as font size and font type (bold, italic, and underline). Once the user clicks the 'Add Text' button, the text editor box will appear separately (figure 33). In this example, we add title text to the water percentage model image map product.
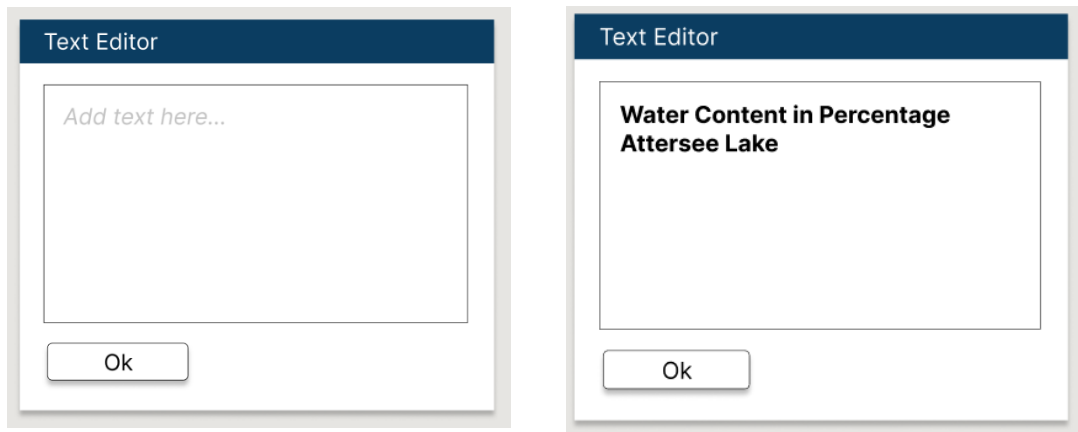
Figure 31. Text editor box

Additionally, the download button is added to allow users to receive the image map in two formats (PNG or GeoTIFF) on their local computer (figure 34). PNG format is intended as the image map together with cartographic map element. Instead, GeoTIFF format is the preserve Sen2Cube.at download capability as the option for the users who would like to do further analysis in RS/GIS/data software.
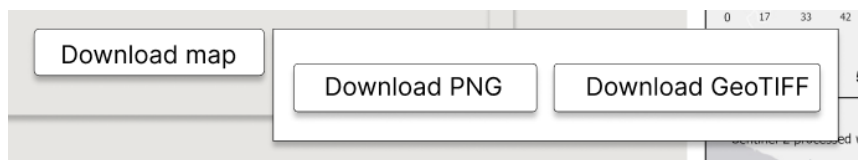

Figure 32. Download button option

6 RESULTS

6.1 Visualization Capabilities Thresholds

Sen2Cube.at system examination is achieved by user evaluation through questionnaires and in-depth interviews. Questionnaire was spread among current active users, most people who already have experience in the Geoinformatics field as students, government staff, and researchers. There are 16 questions divided into three main sub-topics: user background, the last two sub-topics focus on UX evaluation both for web map use and visualization aspect. The purpose of this questionnaire is to gain information about the need of users, particularly in potential visualization improvement. Most of the participants utilize Sen2Cube.at web application to retrieve spatial enrichment semantic data based on polygon subset or object of analysis. Both purposes are then visualized as an image map or chart graph. From the second sub-topics, users are satisfied with the current GUI of Sen2Cube.at. However, they also agree that the improvement of image map is needed, as they mostly modify the image map visualization through other software. Finally, the last sub-topics specified the need for visualization improvement might be applied through the two most voted visualization tools: symbology and legend widget and cartographic element widget.

An in-depth interview with three core users is the latest part of the user evaluation stage. The purpose is to discover specific problems with UI and usability of Sen2Cube. Specifically in the visualization of image map product by completing two tasks and a post discussion. Based on task performance, emerged issues relating to the usability of Sen2Cube.at are appearing in the domain of tools efficiencies such as draw tool for polygon and temporal subset. The question and answer session afterward focused on how the symbology and legend represented the information from image map results. In addition, they alerted several concerns about the misleading and mismatched color ramp.

Additionally, they also mentioned the preference for having discrete data type option in symbology. To understand how the visualization tool could be implemented in Sen2Cube.at, in the last session of the in-depth interview the participants were asked to examine several web mapping applications that provide visualization modification tools. Three of them agree that ColorBrewer2.0 is the best option for accommodating their need.

SWOT analysis supports the potential of visualization improvement as one of the solutions to improve the Sen2Cube.at UX (see subchapter 4.2). The results from SWOT analysis together with user evaluation are the concept behind visualization capabilities thresholds. In practice, those concepts are then formulated into the guideline of map layout and map element format and a set of image map models (see subchapter 4.4). Map layout format guides how the image map in portrait and landscape orientation is implemented using cartographic rules. It's also specifying the placement of map elements might be according to the cognitive cartography principle. Map elements guideline expounds the properties of legend and map scale might be designed for image map respectively. A set of image map models is created based on inference model blocks that are used during the user evaluation stage. There are six image map models that follow both map layout and map elements guidelines.

6.2 Visualization Capabilities Prototype

An interactive prototype is created by defining the UI wireframe beforehand. Wireframe assures the function of UI feature supports user task-flow. The majority of users, will go directly to the view window the see the result after executing the inference mode. They will decide if the result(s) meet their expectation then they will click the download button as the last step of the task-flow. If the result needs some correction, then the user will go back to the main homepage in order to modify the inference model block. Wireframe of the visualization tool then might be placed between the 'viewing the result' and 'downloading the image map'. Figure (34) illustrates how the workflow of the wireframe is implemented.
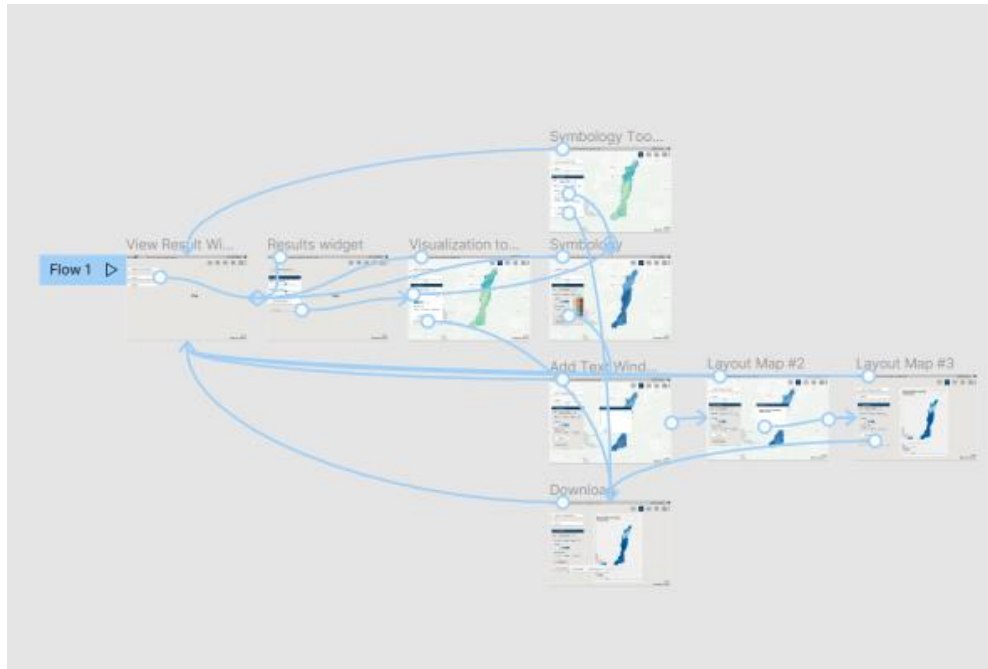

Figure 33. Wire that connecting the layers based on task flow

The wireframing techniques include Lo-fi and Hi-fi wireframe. The Lo-fi wireframe was created as the fundamental concept of the web new features. Thus, the Hi-fi wireframe is the concept for UI prototype. Visualization capabilities improvement is established to accommodate the user's need for creating image maps by applying the cartography principle through an interactive tool. 'Visualization' menu window is created, which comprises two visualization tools: symbology widget and cartographic element widget. The symbology widget contains tools that allow the user to modify the layer symbology (see figure 29). The nature of data in Sen2Cube.at is continuous. However, from the user perspective, this data type is not quite suitable for the inference product that they create through the web application. Therefore, changing layer data type into discrete is possible through the 'data type button' together with data classification (see figure 29). Accessing the color ramp option is designed by clicking the color ramp selection. The library of color schemes refers to ColorBrewer2.0 master color scheme that was generated in the d3js library. In general, there are two types of color schemes: multi-hue and single hue.

The second tool is the cartographic element widget which provides add/remove map elements capability. Concerning the user evaluation, there are three main map elements that usually they add when creating image map: scale, legend, and basemap. Scale and

legend properties are specified in map elements format guideline (see attachment 3). However, they also mentioned that a text editor is also can be an option for them to add short text to their text, such as a title and brief explanation about the symbology value representing. The task flow is completed as the user click the download button, which gives two option of map format version: PNG or GeoTIFF. PNG format will include the map elements and text that were selected before, instead of GeoTIFF as the preserved image download in the current Sen2Cube.at system. All of this layer of UI sequentially follows the intended task flow (see figure 27) formed as a Hi-fi wireframe, Thus demonstrated in Hi-fi UI through Figma web application with the interactive animation which can be accessed through this embed link [Hi-fi Sen2Cube.at prototype](#).

7 DISCUSSION

This chapter discusses the solution and issues while addressing the study objectives. Broadly, User-Centered design paralleled with the modern cartography method is the main scope of this study, then use Sen2Cube.at web application as the object of study concerning the rising number of active users. The study begins with inspecting Sen2Cube.at system thoroughly from the stakeholder and the users side. This examination process aimed to collect comprehensive information about the current condition Sen2Cube.at as the foremost satellite imagery semantic enrichment web application. At this point, several concerns have emerged. One particular concern is the visualization of inference model image map. As a result of this, the assessments that were conducted in this study focused on how to improve concerned matter from a cartography point of view, resulting in concept and practical visualization capabilities thresholds. Web application as the medium for visualizing image map products has emphasized this research into UI prototype method in regard to cartographic interaction tool. Finally, visualization tools prototype and a Hi-fi wireframe were created as the medium for communicating the possible cartographic UI designs of the Sen2Cube.at system.

Visualization Capabilities Improvement

Addressing the first objectives of the study is started by understanding Sen2Cube.at system objectively, because it is important to balance the information from the developer team and user side. Several formal/informal discussions with the Sen2Cube.at team were conducted due to gathering the information from the developer side. Roughly, visualization capabilities of the web application appeared as one emerging issue that potentially as the focus of this study. In the meantime, the SWOT analysis process also started.

User evaluation session is performed in two sessions: questionnaire and in-depth interview. Referring to a study by Newman (2010); the more web application is developed, it is important to take into account usability, user satisfaction, and applicability relating to the purpose to build for. Questionnaire user evaluation is aimed to gather information and issues that the user might face while they perform their task on Sen2Cube.at web application. The questionnaire is formed that helps ensure the visualization capabilities of Sen2Cube.at matter also considered by the users. Considering the statement from Kraak & Brown (2001), web map designers must consider user's charactersitcs and needs as well as the purpose of map. Therefore, the first part of the questionnaire focuses on the user's background to understand the level of expertise and goal of map use. The second and third parts mostly discuss the UI usability concerning image map visualization as a product. An interesting result is shown in the part of the satisfaction statement of image map. Ten out of 15 participants are satisfied with the current image map. However, the result of the symbology examination of the Innsbruck green space image map, a subset of the participants stated that they experience difficulty in understanding the color ramp value and the mismatch between object and the color symbology.

Further, in the third part of the questionnaire, a question concerning the potential of visualization tool is asked, resulting in the majority of the participants supporting symbology and cartographic map element widget to be added in Sen2Cube.at web application. The cartographic map element widget is also considered because 63% of the user download the GeoTIFF map as the last step of their task. Thus they will continue to use any software that supports spatial data for further analysis and modify the image

map visualization. Results from map elements questions confirm that three fundamental map elements commonly added while they modify the visualization, those are: legend, scale, and basemap. In addition, several users mentioned about include the text box for adding title and short text to their image map. This particular request is stated as they would like to disseminate the image map to broader audiences (i.e., research report, scientific article). This fact enriches the position of web map users in map use cube theory as predicted by Kraak & Brown (2001), in which the position of exploratory cartography means that map use for revealing unknowns and high human interaction. To be precise, the use of web map is no longer read map, since the web map users carry the geoinformatics skill (private audience) then they become map producer (presenting knowns). Therefore, the interaction demand becomes high. Nevertheless, other evaluation cartography approaches could be alternatives to addressing similar purposes, such as eye-tracking movement by Horbinski et al. (2021) and the multi-criterion method proposed by Sterba et al. (2014).

The questionnaire form was broadcasted among the users through Sen2Cube.at email on their behalf. As a result, 15 participants participated in the survey. The majority of the participants acknowledged the mentioned issue. However, the number of participants is considered to lack proof for user evaluation quantitative assessment. Therefore, incorporating with the in-depth interview as a qualitative assessment was conducted. Examination of the usability of UI was conducted, with one of the assessments is image map visualization testing. The first part of the in-depth interview is completing certain tasks. Those tasks require the user to execute two inference models that create image map as the final step. 'Water Percentage' and 'Vegetation v.s Baresoil' inference model were selected since both models represent variety of entities. Once the model was executed, participants were asked to interpret the image maps regarding the symbology. They faced similar concerns about the visualization capabilities from the previous user evaluation session. Additionally, during the participants completing the tasks, several web application features were examined as well. As mentioned before in the SWOT analysis subchapter, the server issue was observed in the second participant session. Image maps that are supposed to be visualized after 'view the result' button is clicked, took more time to appear. Another usability concern that was revealed is the polygon draw tool. Although the participants have remarkable skills in geoinformatics, the tool is still not in nature. The last session discusses visualization improvement in practical sense by examining selected web map applications. Those web applications were selected because of their remarkable visualization concept that potentially applied to Sen2Cube.at system.

SWOT analysis table summarized the prominent points of Sen2Cube.at system examination. Thus, shaping the concept of visualization capabilities thresholds which is the result of the first objectives of this study. The, the ideas was then formulated into guideline documents as a practical suggestion for Sen2Cube.at developer in due to improving the image map product. The first guideline focuses on map layout design by applying the concept of cartography design, which considers the shape of the map field, balance, and cognitive cartography principle. The second guideline is expounding the design of legend and scale as the user preferred map elements. Current design trends influenced the process of designing both map elements. To do so, map exploration among GIS and cartography community was initiated.

Designing User-Centered Interface

Another goal of this study is to draw conclusions about User-Centered geovisualization tools that are needed by the current users, particularly in terms of inferring the semantic enrichment image maps. Therefore, the second part of this research narrowed to developing UI design for cartography interaction tools. Prototype for two interaction tools then developed to accommodate user's demand. There are symbology and cartographic element widget. UI design is limited by a wireframe scenario, yet the wireframe follows a certain user task-flow. Determining which task-flow to follow is drawn on general task-flow of users as described through user evaluation. By limiting into certain task-flow ease the developing process of wireframe and UI design. Initiate work of wireframing is sketching interfaces for each task-flow step. At this point, the paper wireframe is the best option since it only requires a simple design and more focus on the concept. Therefore, any refinement and modification could be done quickly. After forming a solid concept of wireframe, then generating it in digital format became the next step. The motivation of choose a Hi-fi wireframe at this stage is fully interactive, clickable prototype and an effective preview of the application. Thus, easy to grasp while demonstrating the feature performance. High fidelity prototype is incorporated as the final product of research. Creating a prototype beforehand enables to make the UI design less time and effort consuming, particularly if the proposed features demand a complex coding algorithm. Additionally, any change can be easily maintained as well during this stage without affecting the system. Despite the interactive and clickable capability, the UI design platform requires designing for each wireframe layers, e.g. from layer 'view result' to 'symbology tool' layer, each action must be designed carefully. Thus, it also demands a tedious wire connecting one layer to another. In addition, designing interaction tool also requires an intuitive aspect that naturally guides users in completing the task smoothly. Color psychology theory must be considered while creating each element of the feature. Figma web application is chosen as the prototype environment because it offers the free use without limiting the access, easy to share, allows collaboration, and provides CSS code of the design. Nevertheless, plenty of options of UI/UX design software are available with similar functionality, for example, Adobe XD, InVision Studio, and Webflow.

Future Opportunities

Refers to Anthony et al. (2005) study, the User-Centered design approach requires a long process of development. After creating a prototype, the process is continued with interaction & usability studies, implementation, and debugging. Formal assessment may include the interaction & usability studies which involve other user testing and internal discussion. Implementing the new feature itself takes evaluation loop examination, as well as debugging process requires adjustment of stability and compatibility of the system. Therefore, an agile system will be promised, which is beneficial for reducing frequent redesign and complex maintenance. Further, the prototype result and guideline documents could be a valuable suggestion for Sen2Cube.at team in terms of bringing the cartography principle into web map application. Moreover, levitating user experience.

It may be argued that cartographers are likely related to UX design field, given the goal of map is communicating information to a targeted audience. One of the Roth (2015) key findings, integration between theoretical principles and practical guidelines from UX/UI field into the cartographic canon, will be next emerging research. Supporting argument from Muehlenhaus (2013); given the shifting phenomenon between map readers to map users through web cartographic interaction, understanding and improving the user experience has become the foremost research topic in Cartography.

8 CONCLUSION

Through this thesis, a series of assessments under applied workflow is established in order to accomplish a goal: improving cartographic web-based visualization capabilities of big EO data analysis results, which take the case of Sen2Cube.at web application. The goal of this thesis is then divided into two main works: to determine the visualization capabilities thresholds and to develop UI prototypes regarding the new features.

User evaluation examination, SWOT analysis together with formal/informal discussion with Sen2Cube.at were carried out as an initial assessment of the system. The purpose of the questionnaire is to gain information about the need of users, particularly in potential visualization improvement. The result from the questionnaire indicates the demand for improving the visualization capabilities of Sen2Cube.at web application, as they mostly modify the image map visualization through RS/GIS software. An in-depth interview is performed with three core users as the latest part of the user evaluation stage. The purpose is to discover specific problems of UI and usability of Sen2Cube.at specifically in the visualization of image map products, by completing two tasks and a post discussion. They alerted several concerns about the misleading and mismatched color ramp. Additionally, they also mentioned the preference for having discrete data types in symbology. The last session of the in-depth interview aimed to examine several web mapping applications as visualization modification tool references. Three of them agree that colorbrewer2.org is the best option for accommodating their need. SWOT analysis is created as the summary of previous evaluations from both parties: internal Sen2Cube.at team and active users. In practice, those concepts were then transformed into two guideline documents, six image map models, which are specified as below:

- Map layout format guideline
- Map elements format guideline
- Green Space in Percentage, Innsbruck City image map
- Water Content in Percentage, Traunsee lake
- Water Content in Percentage, Attersee lake
- Water Content in Percentage, Confluence of The Salzach and The Almbach river
- Vegetation Percentage of Agricultural area, Zell Am See
- Baresoil Percentage of Agricultural area, Zell Am See

The second work is implementing visualization tool feedback from user evaluation as a UI prototype. UI design requires a solid concept of wireframe to be determined before. Therefore, in this thesis two types of wireframes were developed. As a note, creating a wireframe must follow certain taks-flow. Thus, a certain task-flow was selected from the user evaluation result. Lo-fi wireframe is employed as the fundamental concept of how the wireframe will work step by step. Afterward, a digital wireframe is created as Hi-fi type together with Hi-fi UI prototype in Figma web application.

Prototypes of the two interaction tools are symbology widget and cartographic element widget. The symbology widget contains tools that allow users to modify the layer symbology based on their preferences. This includes layer selection, data transform, and color ramp button. The library of color schemes refers to ColorBrewer2.0 master color scheme that was generated in the d3js library. In general, there are two types of color schemes: multi-hue and single hue. The second tool is the cartographic element widget which provides add/remove map elements capability, those are: legend, scale, and

basemap. Additionally, users also mentioned that a text editor is also can be an option for them to add short text to their text, such as a title and brief explanation about the symbology value representing. The UI prototype can be accessed through this embed link [Hi-fi Sen2Cube.at prototype](). Creating a prototype beforehand enables to make the UI design less time and effort consuming, particularly if the proposed features demand a complex coding algorithm.

Nevertheless, this thesis does not free from criticism points. The number of participants is considered to lack proof for user evaluation quantitative assessment. The solution to this issue is to conduct an in-depth interview with core users. Despite the interactive and clickable capability of Hi-fi prototype, the UI design platform requires designing for each wireframe layers, and it also demands tedious wire connection from one layer to another. In addition, designing interaction tool also requires an intuitive aspect that naturally guides users in completing the task smoothly. This thesis brings concepts of how to improve web-based visualization tools, particularly in big EO data analysis web application, by applying modern cartography principles. The future work might continue to the next stage, such as interaction & usability studies, implementation and debugging. Besides the above results, this study is also proof that modern cartography methods are still relevant to be applied to web map applications by incorporating with UI/UX study. So, the user experience could be levitated.

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ATTACHMENTS

LIST OF ATTACHMENTS

Bound attachments:

Attachment 1   A set of Image Map models

Attachment 2   Map layout format guideline

Attachment 3   Map elements format guideline

Free attachments

Attachment 5   Poster

Attachment 6   SD Card

Structure SD Card

Attachment 7   Questionnaire form (html)

Attachment 8   Questionnaire result (excel sheets)

Attachment 9   In-depth Interview questions

Attachment 10   UI wireframe layers (pdf)

Attachment 10   UI prototype animation

Attachment 11   Website

Attachment 12   Thesis Text

Attachment 13   Poster

Water Content in Percentage
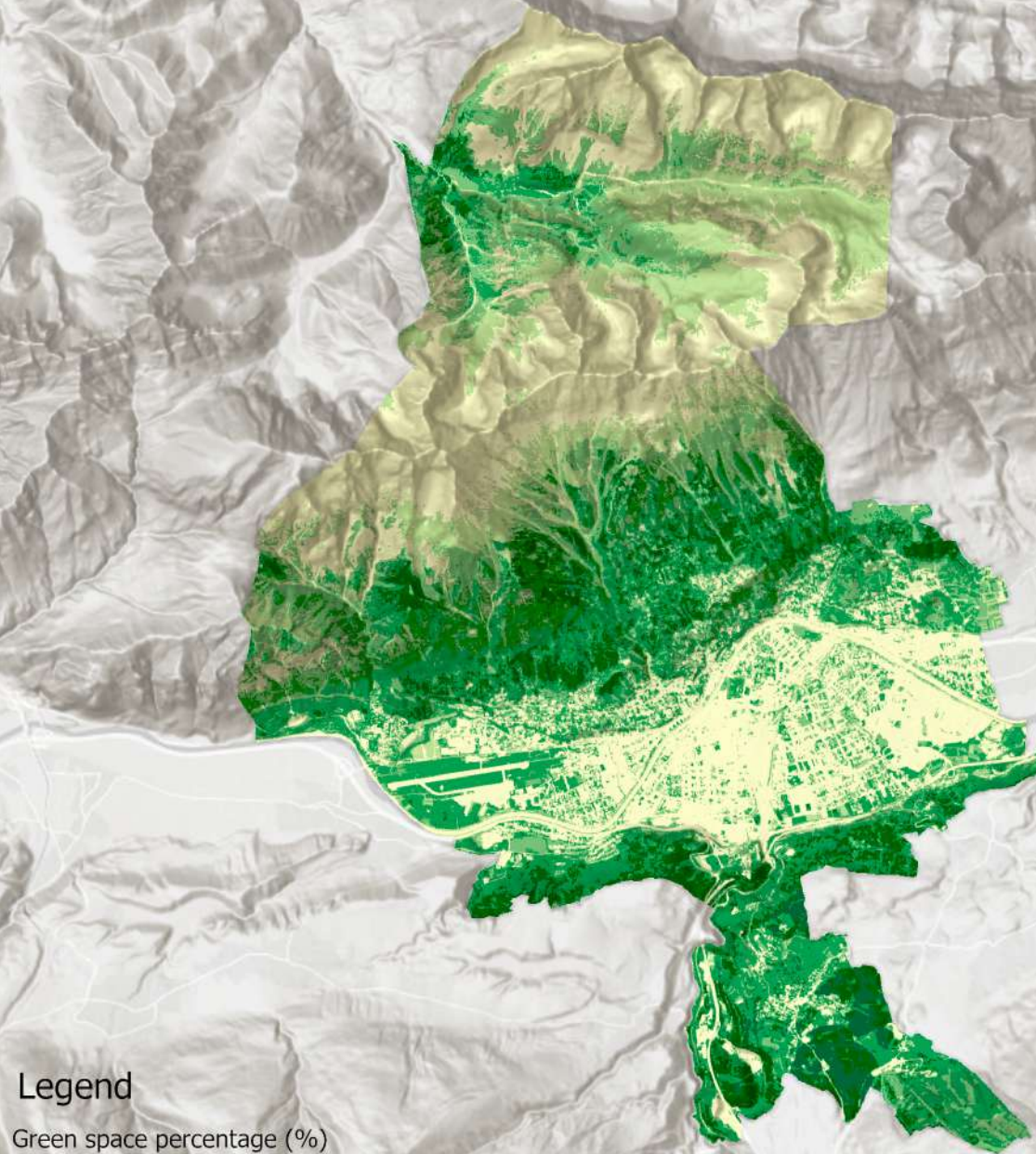# Attersee Lake
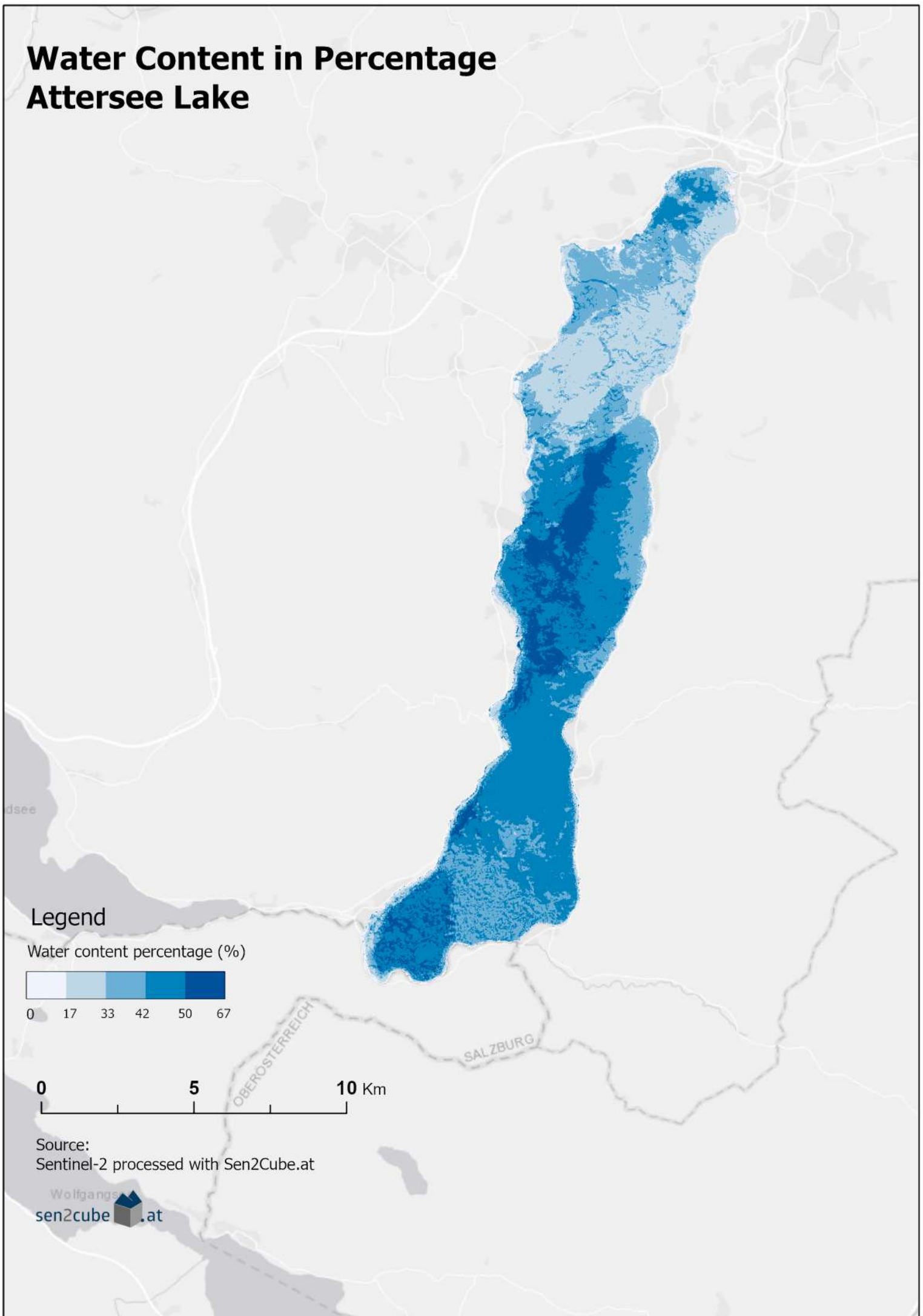
Legend

Water content percentage (%)

0   17   33   42   50   67

0   5   10 Km

Source:
Sentinel-2 processed with Sen2Cube.at

sen2cube   .at

Water Content in Percentage
Traunsee Lake

0	17	33	42	50	67

0   3   6 Km

sen2cube .at

Green Space in Percentage
Innsbruck City

Legend

Green space percentage (%)

0	9	18	27	37	53

0   8,5   17 Km

Source:
Sentinel-2 processed with Sen2Cube.at

sen2cube .at

Water Content in Percentage
Cofluence of The Salzach and The Almbach river

Legend

Water content percentage (%)

| 0 | 17 | 33 | 42 | 50 | 67 |

0   0,5   1 Km
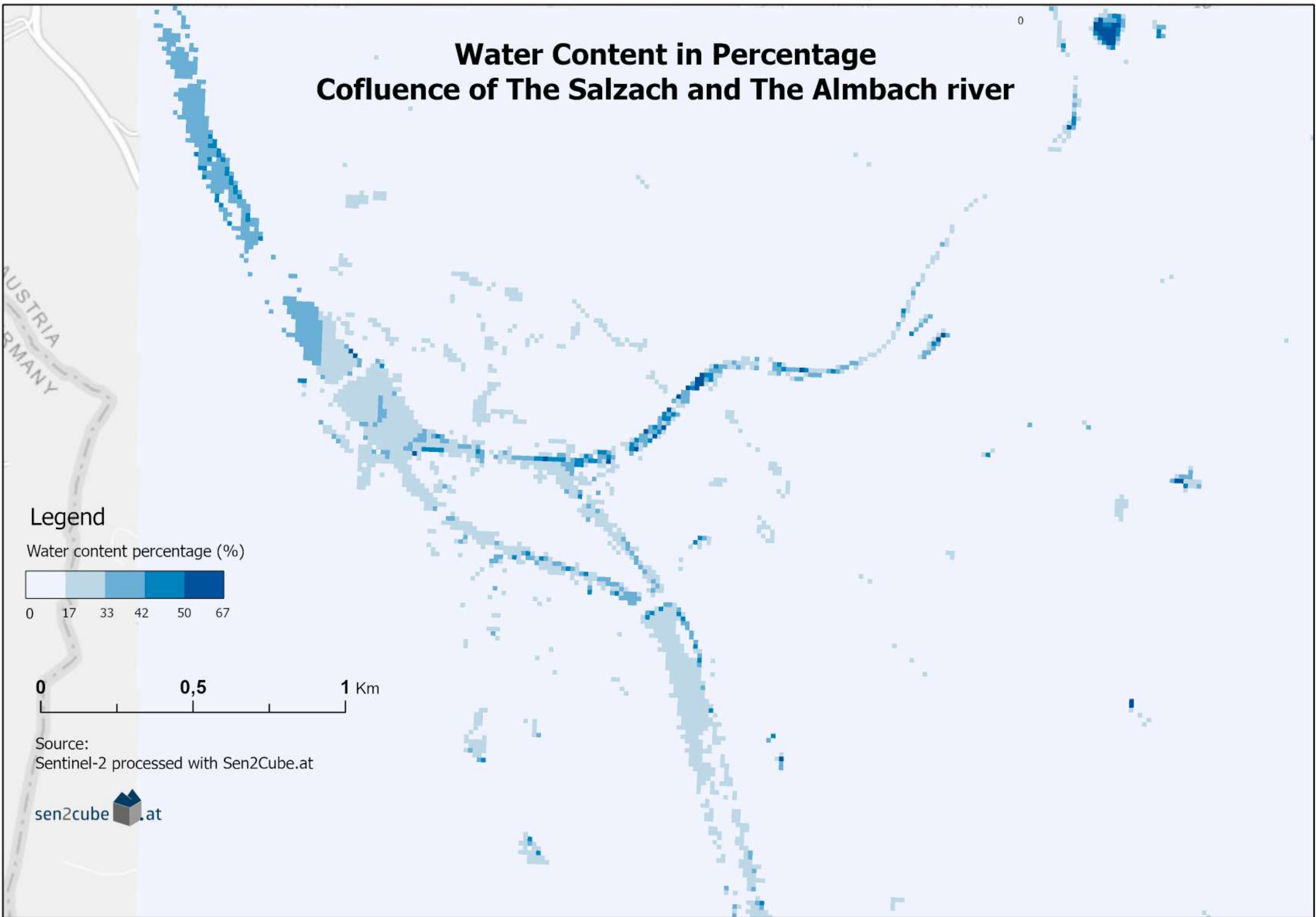
Source:
Sentinel-2 processed with Sen2Cube.at

sen2cube .at

Baresoil Percentage of Agriculture area
Zell Am See

Schüttdorf

Bruckberg

Aufhausen

Zellermoos

Fischhorn
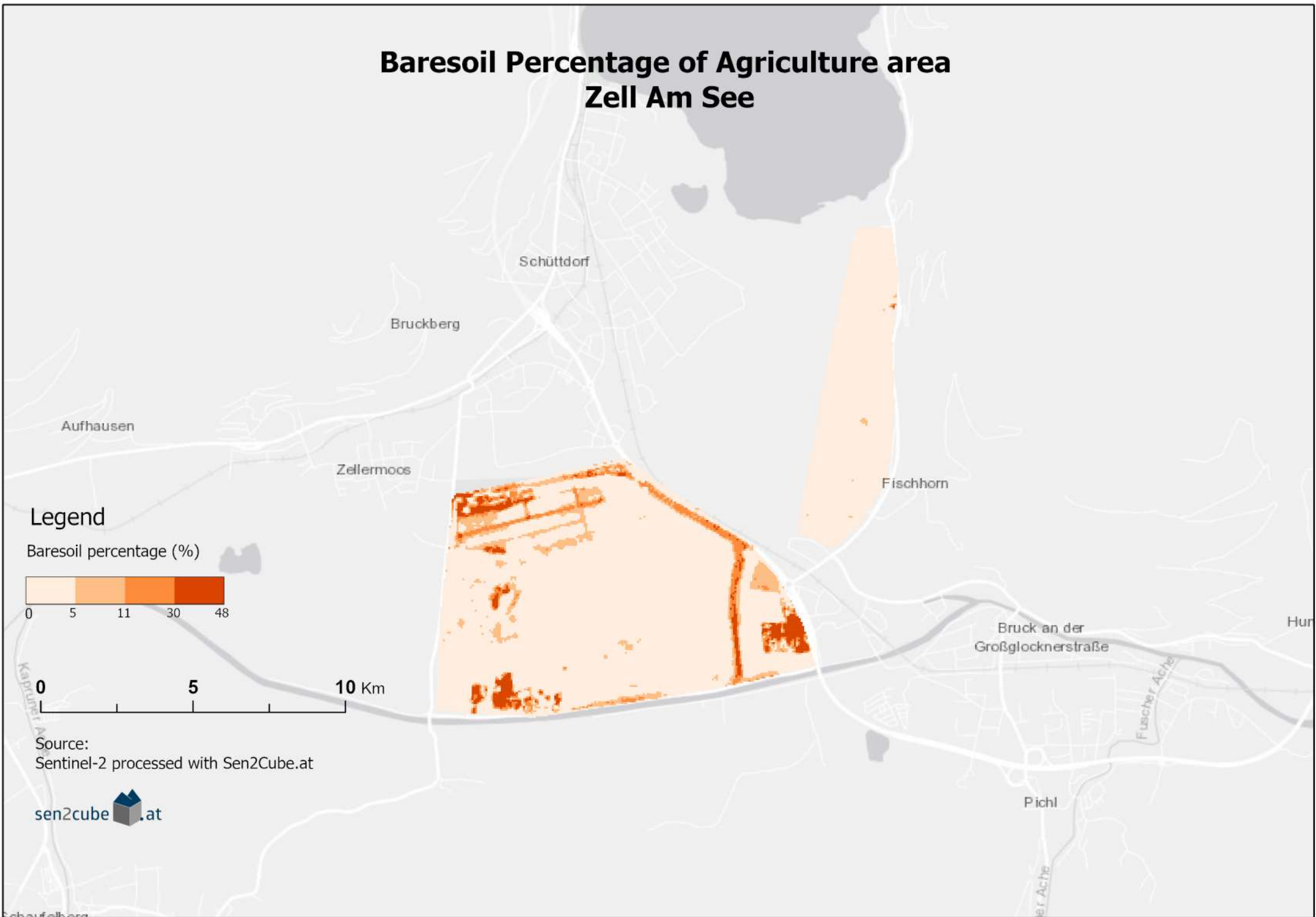
Legend

Baresoil percentage (%)
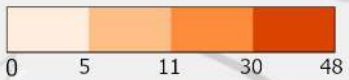
| 0 | 5 | 11 | 30 | 48 |

Bruck an der
Großglocknerstraße

Hur

0   5   10 Km

Source:
Sentinel-2 processed with Sen2Cube.at

sen2cube.at

Pichl

Vegetation Percentage of Agriculture area
Zell Am See

Schüttdorf

Bruckberg

Aufhausen

Zellermoos

Fischhorn

Bruck an der
Großglocknerstraße

Hund

Pichl

chaufelberg
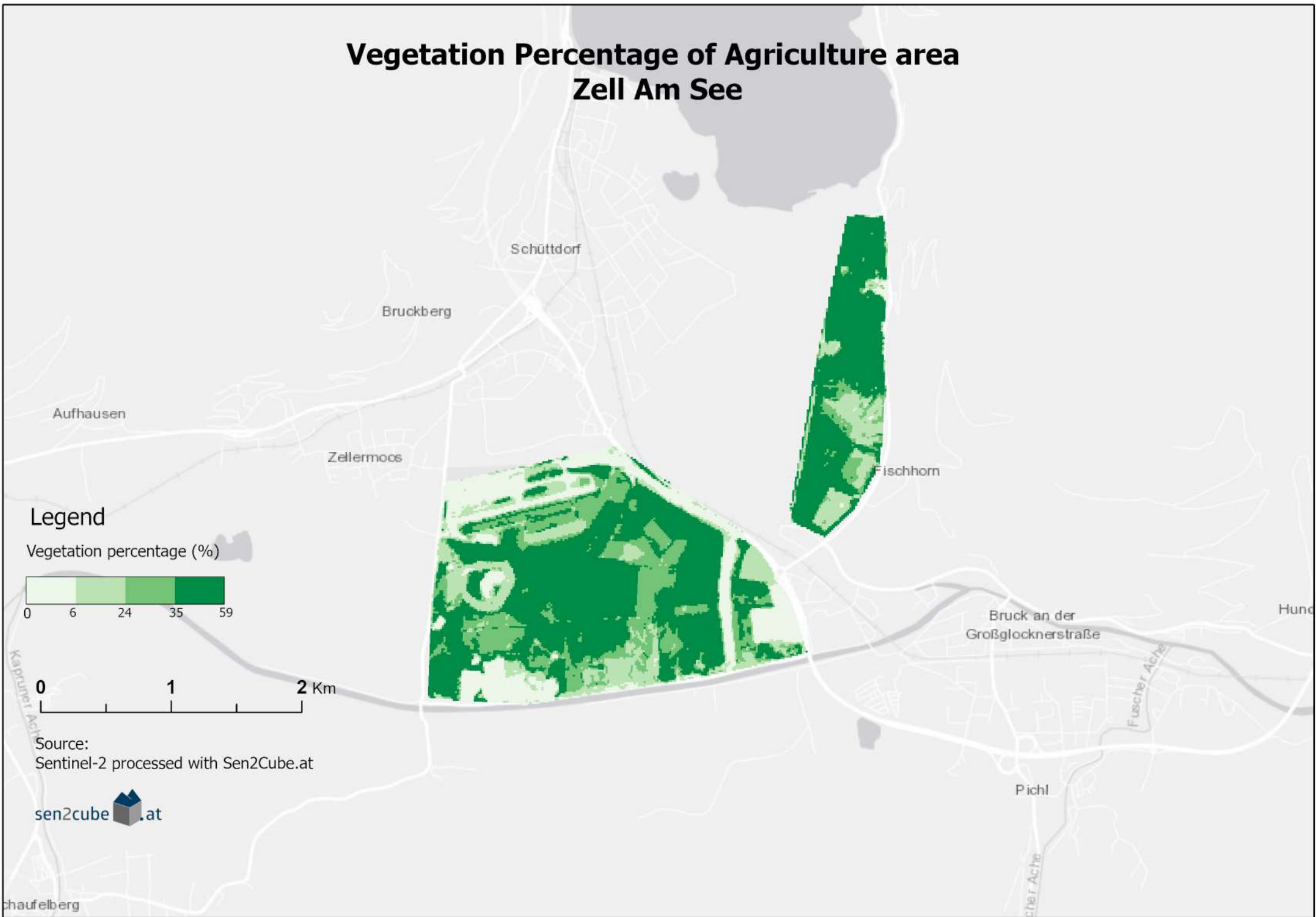
Legend

Vegetation percentage (%)
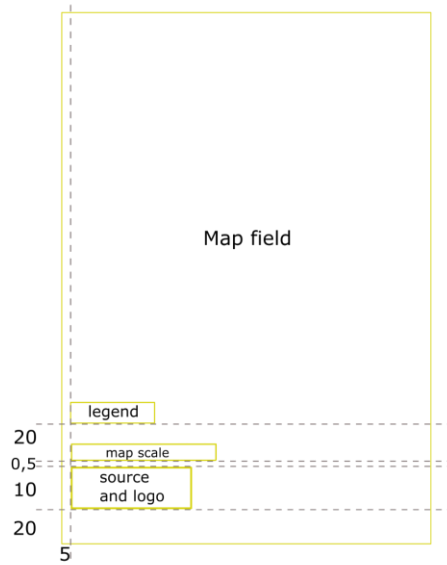
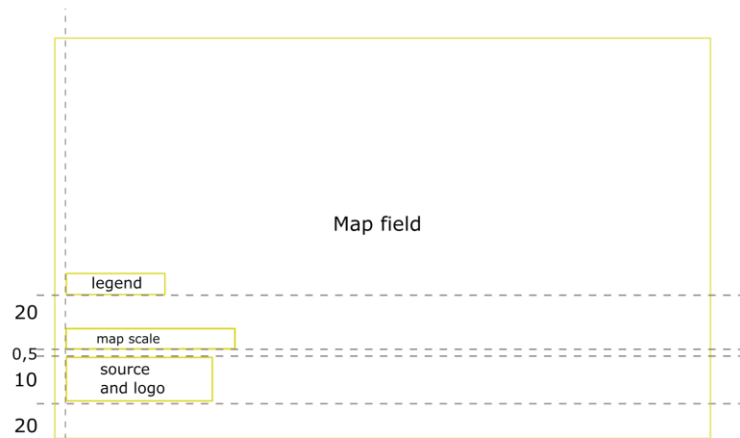0   6   24   35   59
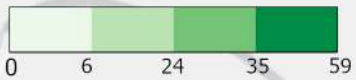
0   1   2 Km

Source:
Sentinel-2 processed with Sen2Cube.at

sen2cube .at

map layout format guideline

file format: png
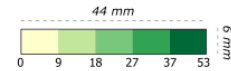orientation: potrait and landscape
dimensions: 3508 x 2480

Map field

legend

20
0,5   map scale
10   source
       and logo
20

5

unit in mm

Map field

legend

20

map scale

0,5
10   source
       and logo
20

5

unit in mm

map elements format guideline

legend properties

44 mm

6 mm

0   9   18   27   37   53

color scheme: ColorBrewer2.org
color model: RGB

line width: 0,5 pt

block size: depends on number of classes

0   9   18   27   37   53

font: Arial regular
color: #000000FF

map scale properties

0   8,5   17Km
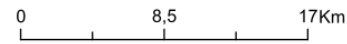
map scale model: Scale Line Metric ESRI
map scale unit: Kilometers
label text: Km
label position: after labels

divisions: 2
subdivisions: 2
marks frequency: 4
marks position: above line

0   8,5   17

lnumbers frequency: 3
numbers position: above line
rounding: true
font: Arial regular
color: #000000FF