EXAMPLES OF SPATIAL ANALYSIS

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Abstract – Examples of Spatial Analysis are illustrated in the contests of Applied Geomatics, Geomatics Applications and related techniques, taking into account Survey and Mapping data sources and methods.

FOREWORD [1]

A brief history of techniques and tools for Data Processing in Architecture

Introduction

Data is information and knowledge collected through observation, usually used for decision-making. Data is collected, processed, analysed, then can be visualized and represented by graphs and images. Many types of data are employed in every aspect of human activity, including architecture design, which requires collecting site information and synthesizing it to make better decisions on the design for different contexts. Therefore, the design process site data collection and processing of. This step is called a survey, which is a method to gather and process information so that the designers achieve a comprehensive knowledge of the study area. Data, usually containing spatial and geographical information in the field of architecture, are collected during the survey by different means depending on how the knowledge and information is recorded.

Besides data collection, the tools and techniques to record information also play a crucial role in the communication of the design results, which is a certain category of information that needs to be presented to clients and the public. The information is primarily related to space, morphology, and geography; therefore, it is essential to show it by simple and clear language, and in most of the time a graphical language. In history, tools and techniques to collect information have been through changes driven by social and technological evolutions. Nevertheless, data collection and visualization in building and construction have only passed a few milestones because architecture was related to a particular cultural identity and thus only changed over a long period. In the author's opinion, the two major steps in architecture design: the data collection and visualization in the survey stage, and the information communication in the design process, are closely related and driven by the same technological innovation force that makes them more efficient and accurate. As a result, the evolution of tools and techniques involved in these two steps follow similar patterns. The above states the reason why they are frequently brought up together.

Before 18th Century

In ancient history, surveying occurred when humans first built large structures. For example, the Egyptians did survey when they constructed Pyramids. The Chinese mathematician Liu Hui described ways of measuring distance in his book published in 263 AD. Later, in ancient Roman, the importance of knowing all aspects of the site when designing a building was stressed by **Marcus Vitruvius Pollio** in his influential

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[1] Excellent preliminary report written by Mingzhen Zhao, Yanyin Chen (china).

manual *De Architectura*. In this book Vitruvius described a variety of surveying instruments, such as the water level or chorobates for measuring slopes, showing that the surveying instruments were essential in all building operations. Apart from surveying used for getting measurements of the site, he also gave a guide on the arrangement of buildings suitable for the climate and the site. In addition, he covered a wide scope of other science useful and serviceable in building activities, ranging from mathematics to astronomy and meteorology. These indicate that Roman architects, who were then skilled in engineering, art, and craftsmanship combined, were required to consider many aspects related to the physical and intellectual life of man and his surroundings. Therefore, Roman architects needed to collect comprehensive knowledge of the construction site.

During the renaissance, drawings and paintings became a tool of survey and investigation, and they are considered as necessary as a documentation illustrating the condition of the site, monuments, and as a record of buildings. In the early 15th century, the Florentine Renaissance Architect **Filippo Brunelleschi** (1377-1446) mastered perspective drawing out of the desire to accurately record and study the magnificent monuments in the ancient city, developing the technique to better depict 3D volumes and spatial relationships. Besides drawings, during the early Renaissance, humanists and artists began to collect antique fragments of artwork for the study. Apart from the buildings themselves, the essential source for the study of classical architecture was the treatise *De Architectura*. **Leon Battista Alberti** (1404-1472), who was involved in various critical architectural projects, consulted the treatise for factual information on building techniques, studied theories of great philosophers, and relied on his own surveys of ancient monuments in Italy and Central Europe. Moreover, because of his mathematical interests, he also developed a technique for drawing maps with polar coordinates referred to a central point, preparing a map of Rome with the Capitol Hill as the reference point.
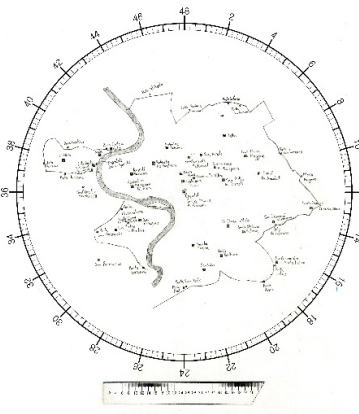
Chorobates   *Alberti's map of Rome*

The most common and most used method to express spatial data is in the form of a map. A map is a spatial model that expresses the geographic distribution of objective things and their interrelationships. It is a graph that reflects geographic entities, and it simplifies and reproduces geographic entities. In the Renaissance, maps were used to impress viewers and establish the owner's reputation as sophisticated, educated, and worldly. Because of this, towards the end of the Renaissance, maps were displayed with equal importance of painting, sculptures, and other pieces of art. Map making is closely related to printing technology. The first maps were manually constructed with brushes and parchment and therefore varied in quality and were

limited in distribution. Later, the creation and improvement of the printing techniques allowed for far more accurate reproductions of maps. In Renaissance, there were two main printmaking technologies: woodcut and copper-plate intaglio, referring to the medium used to transfer the image onto paper.

When it comes to tools to express ideas, buildings that were built before the Renaissance were built without architectural notations in the modern sense of the term – and often without any medium used to transfer the image in an architect's mind onto paper at all. The main notational tools for the building were physical models that architects used to carve the models showed their workers. It was only in the second half of the 15th century, **Leon Battista Alberti** emphasized the value of drawings and paintings as the original act to conceive a building, and buildings are only copies of them. Take as an example the treatise *Trattato di architettura* written by **Francesco di Giorgio Martini** (1439–1501). He elevated the status of architecture to a noble art and urged that the architect express concepts through the medium of drawing over writing. The treatise itself has large amounts of illustrations, making it possible for readers untrained in architecture to grasp complex passages in visual terms.

18th-20th Century Modern Area

The 18th century is the age of reason. During this period, science, which is considered the most rigorous and objective way to gain knowledge, has acquired a dominant position in human activities. Modern techniques and instruments for surveying had begun to be used, allowing information recording to be more accurate. For example, the precision theodolite, a tool for measuring angles, made a significant step toward the measurement's accuracy; also, detailed triangulation network surveys could map many countries. The first industrial revolution stimulated significant technological development from 1760 to 1840. This exerted an effect on surveying, which became increasingly important with the introduction of steam locomotives in the early decades of the 19th century. Surveying was necessary because railroads should be planned technologically, and routes should be financially viable. It should also be noted that in 1808, Napoleon Bonaparte founded continental Europe's first cadastre making it fundamental to gather data on the number of parcels of land, their value, land usage, and names.

Hand drawings **a**nd physical models had always been the tools to record and transmit visual ideas. However, in 1842, the blueprint, a reproduction of architecture and engineering technical drawings, was introduced by John Herschel. This technique allowed the rapid and accurate production of an unlimited number of copies.
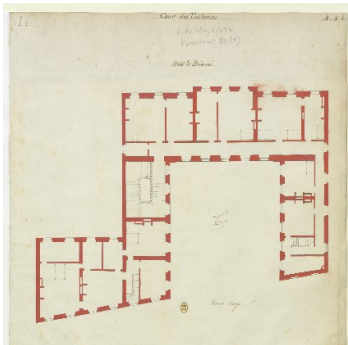

Plan of the main floor of the of the Hôtel de Brionne in Paris
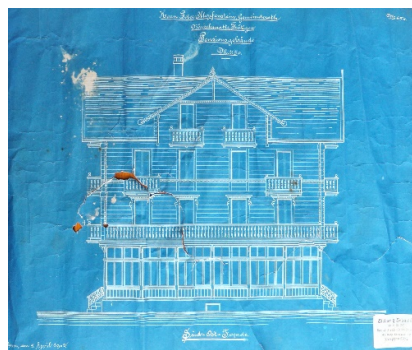
Architectural drawing in blueprint, 1902

20th Century Enlightenment of the Digital Area

During the 20th century, maps became ample because the improvements in printing and photography made the production cheaper and more accessible. Many new projections were constructed to make the representation of the earth more accurate. For instance, the Two-Point Equidistant projection was drawn up by Hans Maurer in 1919, and the Loximuthal projection was made by Karl Siemon in 1935.
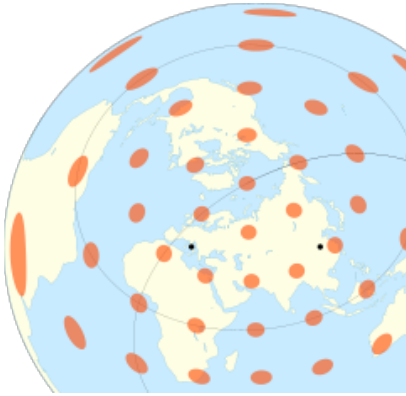
*T*wo-point equidistant projection
of the entire world (the two points are Rome, Italy and Luoyang, China)

Loximuthal projection of the world

The improvement of printing techniques also influenced the expression of architectural design outputs in modern architecture. In the early 1940s, blueprints began to be substituted by whiteprints, for reproducing architectural and engineering drawings because the process was more straightforward and involved fewer toxic chemicals. It is a contact printing process which accurately reproduces the original in size but cannot reproduce continuous tones or colours. The whiteprints were later replaced by large-sized xerography machines, which are standard copy machines using toner on bond paper. After the introduction of computer-aided-design techniques and commercial printers, the designs were then directly printed by a computer printer or plotter.

In the mid-to-late 20th century, significant progress in electronic technology has led to a further revolution in data collection and communication. Computers, which help to store, sort, and arrange data, were used in mapping to create map projections. Computer hardware, such as computer screens, plotters, printers, scanners, and analytic stereo plotters are designed to visualizing information, image processing, spatial analysing, and do advanced map-making. With computers, people can make maps capable of showing tiny different features.

Aerial photography and satellite images have provided digital raster graphics with high-accuracy, high-throughput methods for mapping the earth's surface over a large scale and different features, such as buildings, streets, and topography. These various physical features can compose a site's multiple layers of information and knowledge, which architects analyse at the beginning of an architecture project. The improvement of photography had also allowed architecture to take pictures of the site during the site visit. The photos, much more accurate than hand drawings, also saved the architect's time spent on recording images by sketches.

During the 1960s, Computer-aided-design (CAD) systems were developed during the period when technological developments in the modern industries provided advancements in three-dimensional surface construction, NC programming, and design analysis. CAD technology helps designers with the creation,

modification, analysis, and optimization, thus increasing the design process's productivity. It provides rchitects and engineers with the possibility of digital drafting.

In the 20th century, surveying has made significant progress. Electronic Distance Measurement (EDM) types of equipment were introduced in the late 1950s. EDM surveying is a method of determining the length, using light waves. The instrument, which allows people to measure distance up to kilometres saved the need for days or weeks of chain measurement. Later in the 1970s, Total Stations, an instrument that measures both angle and distance, largely improved the accuracy and speed of measurement. The first satellite-based geo-positioning system was the Transit System, firstly used by the U.S. Navy to provide accurate location information to Polaris missile submarines. The system entered Naval service in 1964 and later was also used for civil purposes. Surveyors used field receivers to determine the location of a point, but the observations were inaccurate because the satellites were too sparse. It was mainly used for establishing benchmarks in remote areas.
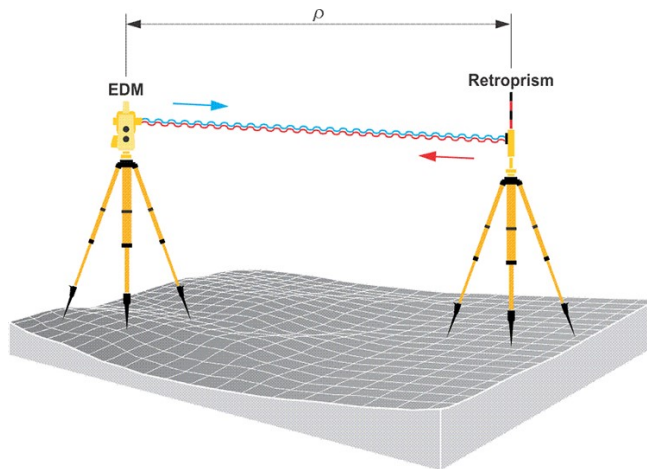
EDM (Electronic Distance Measurement)   Total Station

Emergence of GPS and GIS

In 1978, the prototype satellites of the Global Positioning System (GPS) was launched. GPS used a larger constellation of satellites compared to those few and scattered of the Transit system. As a result, accuracy and signal transmission were improved. The development of disciplines related to the processing and analysis of spatial data, including geography, cartography, photogrammetry, remote sensing technology, mathematics and statistical science, computer science, gave birth to the Geographic Information System (GIS). The means of recording information include numbers, characters, symbols, sounds, and images. For a computer, data refers to all phenomena (numbers, words, symbols, sounds, images, etc.) that are input to the computer and can be processed by the computer. In a computer environment, data is the only tool for describing entities or objects. Geographic information is spatial information, and its position is identified with data, which is the most obvious sign that geographic information is distinguished from other types of information. This positioning feature is the spatial position recognition through the geographic coordinates established by the latitude and longitude network or the kilometre network. Geographic information also has multi-dimensional structure, that is, the realization of the multi-thematic 3D structure based on 2D space. The connection between various thematic and entity types is carried out through attribute codes, which provides the possibility of comprehensive research between the various layers of the geographic system, as well as

the multi-level analysis of the geographic system and the transmission and screening of information provided convenience. A system that can collect, store, process and reproduce data and information, and can answer a series of questions from users is called an information system. The four functions of the information system are data collection, management, analysis, and expression. The information system is a question and answer system based on a database. In the process of assisting decision-making, information systems can provide useful information. From the perspective of computer science, the information system is composed of four main parts: hardware, software, data, and users. In the computer age, most important information systems are partially or fully supported by computer systems. In fact, the geographic information system (GIS) is supported by computer hardware and software, mainly to collect, store, manage, retrieve, analyse and describe the location and distribution of space objects and attribute data related to it, and answer user questions. The establishment of a Geographic Information System (GIS) is a process in which information or data flows in a certain way. The development of GIS in the 20th century can be divided into the initial development stage in the 1960s, the development consolidation stage in the 1970s, the promotion and application stage in the 1980s, and the vigorous development stage in the 1990s. In the 1970s, the rapid development of computer hardware and software technology, especially the use of large-capacity storage devices, promoted the development of GIS in the practical direction. Different topics, different scales, and different types of unique geographic information systems It has been developed in various parts of the world. The United States, Canada, the United Kingdom, West Germany, Sweden, and Japan have invested a lot of manpower, material resources and financial resources in the research of GIS. In the 1980s, due to the rapid development of computers, GIS gradually matured and was widely promoted and applied throughout the world. The field of application continued to expand. The combination of GIS and satellite remote sensing technology began to be used for global problems, such as global changes and Global monitoring, global desertification, global habitable area evaluation, El Niño, acid rain, nuclear proliferation, and nuclear waste. The United States Geological Survey used a geographic information system to respond to the US Three Mile Island nuclear leak within 24 hours, and quickly conducted an impact assessment of nuclear proliferation. In the 1990s, with the establishment of geographic information products and the popularization of digital information products all over the world, GIS has become a definite industry. The GIS system in use has doubled every 2 to 3 years. The annual growth rate is more than 35%, and there are more than one thousand GIS manufacturers. GIS has penetrated all walks of life, involving thousands of households, and has become an indispensable tool and assistant for people in production, life, learning and work. At the end of the 20th century, web mapping emerged. Web mapping is a process of using the maps delivered by GIS in the World Wide Web. It is a web cartography service that focuses on geodata processing. In 1993, Xerox PARC Map Viewer, one of the earliest static web mapping sites, was developed by Steve Putz. In 1996 the Centre for Advanced Spatial Technologies Interactive Mapper was established. It would allow the user to select a geographic extent, a raster base layer, and a number of vector layers to create a personalized map. In 1998, MapObjects Internet Map Server marked ESRI's entry into the web mapping business.

21st Century Advanced Digital Area
The digital era has brought evolution to the architecture and engineering industry. The rapid development of surveying, mapping, mathematics, and digital technology have greatly improved the tools and techniques for data analysis of the architecture design and the communication of the concept. Various digital tools were

created. These digital tools use mathematics, computer science, and other disciplines to simulate the complex physical world. They have given architects the ability to record and transmit visual ideas and the ability to analyse and manage multiple layers of information acquired from the physical world. Architects thus have much more accurate site knowledge and better means to analyse the data. Architecture design needs a thorough understanding of the sites, as was paid much attention to since the Renaissance. Although hand-made drawing is still an excellent way to transmit concepts, 3D modelling techniques allow architects to have a more precise and objective representation of their idea. Furthermore, parametric design, which visualizes complicated engineering calculations, eliminates vague and random thoughts, making the design process more rational and adaptable. Digital fabrication, such as 3D printing, is also promising to improve the productivity in prototyping.

Entering the 21st century, the theodolite, total station, and RTK GPS surveying remain the primary methods. Remote sensing and satellite imagery continue to improve and become cheaper, allowing more frequent use. Prominent new technologies include three-dimensional (3D) scanning and the use of lidar for topographical surveys. UAV technology, along with photogrammetric image processing, is also appearing.

GIS

With the popularization of GIS software, GIS is used in architectural research and practice, especially in architecture and urban design. GIS may be used in many phases of the architectural design process, from analysis to design to communication. The benefit of GIS lies in its analytical capabilities, wherein multiple phenomena can be linked by location and viewed through a spatial perspective. Information on an area can all be taken into consideration when planning a structure or selecting a site. GIS helps to connect data and define the relationship between preliminary knowledge in socioeconomic, function, construction, and environment. GIS gathers different urban and architecture site spatial features and is capable of doing multi-layered analysis and creating thematic maps. The combination of natural elements such as slopes, risks, and threatened natural areas can be displayed as constraints which will impact the design decisions. GIS technology can also be used to compare redesigned urban maps overtime to interpret the evolution of urban fabric. Its visual analysis can be applied to different cities to measure visibility. In the architecture and urban design process, GIS is often used in conjunction with other visualization tools, such as AutoCAD, Google Earth, Adobe Illustrator, and Google Sketchup, to create dynamic and complex models.

Besides creating models, web maps can also facilitate architecture design by giving designers the possibility to have virtual site visits. This will primarily help the context analysis as well as save them time and money cost of an architecture design project. At present, with the rapid development of computer software and hardware technology, database technology, network technology, multimedia technology and other computer technologies, the application field of GIS is also rapidly expanding. The information processing mode of GIS has shifted from the previous centralized mode to the client/server mode. The open GIS of resource sharing has been greatly developed by the realize cross-regional spatial data and geographic information processing under network support and distributed environment. In addition, the combination of GIS and various application models (such as environmental model and rainfall model), the further integration of GIS with GPS and RS, and the application of parallel processing technology in GIS have all developed to a certain extent. Moreover, these developments of GIS are not isolated, but they influence and promote each other. Its

purpose is to promote the construction and development of the geographic information industry and better serve human understanding and protection of the environment on which humans depend [2].

Web Mapping

There are many ways to express spatial data. In the 20th century, the carrier of spatial information can be recorded on the either on a disk in digital format or a map recorded on paper. Whilst in the 21st century, Web mapping can be regarded as a significant new trend in cartography. Web mapping has brought many geographical datasets, including free ones generated by OpenStreetMap and proprietary datasets owned by HERE, Google, Tencent, TomTom, and others. A range of free software to create maps has also been conceived and implemented alongside proprietary tools like ArcGIS.

3D modelling

Physical models have been an old-fashioned but effective way to create excellent overviews of a building and express new design ideas. In the 21st century, physical models are still good ways to analyse the site and communicate information. However, virtual 3D models take over the roles listed above, and they are more accurate and quick than handmade models. 3D models are good ways to have a better visualization of projects. In 3D computer graphics, 3D modelling is the process of developing a mathematical representation of any surface of an object. There exist three accessible processes to represent a model:

❑ Polygonal modelling: points in 3D space are called vertices connected by segments to form a polygon mesh.

❑ Curve modelling: surfaces are defined by curves, including non-uniform rational B-spline (NURBS), splines, patches, and geometric primitives.

❑ Digital sculpting: the most widely used applications of this type is displacement. It is a dense model (often generated by subdivision surfaces of a polygon control mesh) that stores new locations for the vertex positions through the use of an image map storing adjusted locations.

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[2] *GIS development in China*: The development and application of GIS started late in China, but the development momentum is rapid. The development of GIS in China can be divided into four stages. The first stage is from 1970 to 1980. In the preparation stage, it mainly prepares for public opinion, formally proposes an initiative, begins to form a team, trains talents, and organizes individual experimental research. Machine-aided mapping and remote sensing applications have made technical and theoretical preparations for the development and application of GIS.

The second stage was from 1981 to 1985, as the initial stage, it completed technology introduction, research data specifications and standards, spatial database establishment, data processing and analysis algorithms and application software development, etc., carried out theoretical exploration and regional experiments on GIS the study. On the basis of the nationwide geodetic survey and the establishment of digital ground models, a scale of 1:1,000,000 national land basic information system and a national land information system, a scale of 1:4,000,000 national resource and environmental information system, and a scale of 1:2,500,000 soil and water conservation information system were completed.

The third stage, from 1986 to around 1995, was the development stage. The research and application of GIS in China entered an organized, planned, and targeted stage, and gradually established organizations and research centres with different levels and scales. The laboratory, the Chinese Academy of Sciences began to prepare for the establishment of the National Resources and Environmental Systems Laboratory in 1985, is a new type of open research laboratory. In 1994, the China GIS Association was established in Beijing. GIS research is gradually combined with national economic construction and social life needs and has made important progress and practical application benefits.

The fourth stage from 1996 to now, China's GIS technology has made rapid progress in technical research, results application, talent training, software development, etc., and strives to push GIS from the initial development period of research experiments and local applications to practical and integrated engineering, to provide auxiliary analysis and decision-making basis for national economic development. In the process of research and application, GIS has moved towards the road of industrialization, has become a tool commonly used in the construction of the national economy, and has played a major role in various industries. In addition, from an application perspective, geographic information systems have been used in resource development, environmental protection, urban planning and construction, land management, transportation, energy, communications, map surveying and mapping, forestry, real estate development, monitoring and evaluation of natural disasters, finance, insurance, Oil and gas, military, crime analysis, transportation and navigation, 110 alarm systems, bus dispatching, etc. have all been specifically applied.

3D modeling is also present in web mapping. Google Earth initially expressed the three-dimensional scene by DOM (image data) + DEM (elevation data) to form a three-dimensional and textured terrain. The modeling method is basically to use DOM to construct the TIN and then paste the DEM. Google Earth uses many surveying and mapping technologies to make its realistic 3D city models. The techniques include tile photography, aerial photography, computer vision, graphics processing. At present, tilt photography can use UAV data, mid- and high-altitude aircraft data, and even satellite data to generate 3D models, and it is fully automatic modeling. The tilt model is the only choice to represent a city-level 3D scene (e.g. many smart cities use this model as a base map).
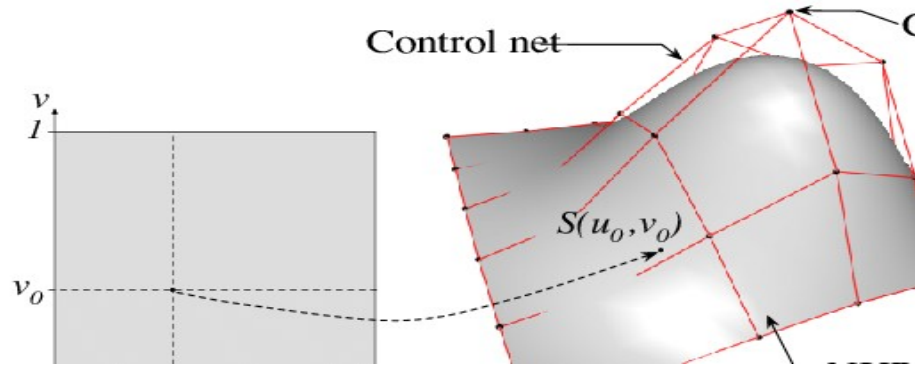
NURBS surface and its parametric plane
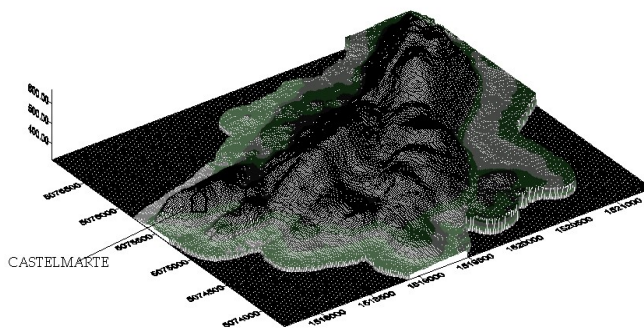
DSM in a hilly zone
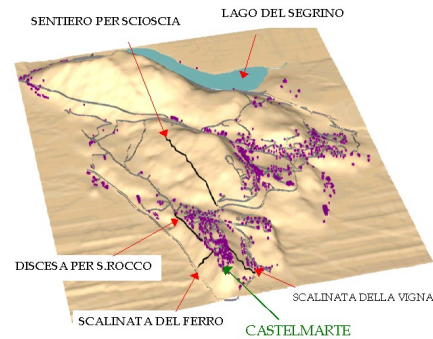
Orthoimage superimposed to a DSM

3D printing

3D printing is another popular application of 3D modeling because it allows precise control of the mesh design. Objects can also be generated by 3D scanning or engraving. It is a rapid prototyping technology based on three-dimensional digital model files. It uses powdered metal or plastic and other adhesive materials to construct objects by layer-by-layer printing or powder casting.

There are many benefits to this technology in the construction field. First, the product of 3D is of high quality. The ink in 3D printing technology is mainly made of cement and glass fiber, which is "printed" by continuous linear extrusion utilizing printer equipment, which is no different from traditional buildings and even more durable than traditional steel-concrete buildings. Second, the products have great insulation performance. The hollow wall greatly reduces the weight of the building itself and facilitates the building to fill the empty "belly" with insulation materials; therefore, the wall becomes an integrated self-insulating wall. Third, the process allows integrative structure. The space for pouring beams and columns is reserved for doors and

windows to solve the load-bearing construction of the wall. It can also print out the facades of houses with various shapes. Lastly, the 3D printing process is favourable for the environment. 3D printing reuse construction waste, including industrial waste, tailings, etc. The application of 3D printing technology in the construction industry has not yet formed a scale. In real life, 3D printing is mainly used in building decoration and building model making. 3D printing physical buildings are still in the experimental stage.

❑ Application in architectural decoration: At present, the application of 3D printing in architectural decoration is relatively mature. Personalized decorative parts have been successfully used in hundreds of thousands of construction projects.

❑ Application of architectural model: In the construction industry, designers use 3D printers to print architectural models. This method is fast, low-cost, environmentally friendly, and beautifully produced at the same time. 3D printed models are the best way to achieve visualization and barrier-free communication of architectural ideas. Fully meet the requirements of the designer, saving a lot of materials and time.

Conclusion

Information is the reflection of the real world in people's minds. People record it with numbers, words, symbols, languages, graphics, images, sounds, etc. for communication, transmission or processing. Information provides people with knowledge about various facts in the real world. Therefore, information is a reflection of the existence and evolution of objective things. Data is a physical symbol used to carry information. Only when a certain meaning is added to it can it represent a certain entity or phenomenon, and then the data becomes information.

Information and data are inseparable and have a very close relationship: information is the connotation of data, the content and interpretation of data; and data is the expression of information. That is to say, data is the carrier of information. Only by understanding the meaning of the data and interpreting the data can the information contained in the data be obtained.

In architecture, it is crucial to process the spatial information for the site knowledge, and to express the geometric form of a design concept. In architecture history, the evolution of techniques and tools for information and data visualization and analysis was closely related to technological advances and social changes. Mapping and surveying technologies influence the way architects acquire knowledge; and printing technologies affect the ways information is expressed.

The evolution has gone through four main stages. Before the 15th century, people used tangible means, such as hand-made physical models, to understand the world. From the 15th to 20th century, artists during the cultural rebirth in Renaissance had made hand drawings on papers a major way to represent ideas. With the development of multiple disciplines including geomatics, photogrammetry, and information technology, digital technologies allow to create rapidly accurate models to represent the complex world.

Information and data in architecture design is a multi-disciplinary integrated spatial information system. The goal of information processing and visualisation is resource management, resource development, macro decision-making and resource information service. With the establishment of the geographic information system and the popularization of 3D modelling tools, digital tools will penetrate into all walks of the architecture design process and become indispensable assistants.

PART I

**Application and investigation for uses in GIS with regards to Agriculture
in Brazil, Angola, and South Africa** [3]

Aim and scope

This report aims to investigate methods, in the sector of agriculture, for GIS application, with a specific focus on remote sensing technology. The problems and opportunities in the Agricultural sector of each country, namely Brazil, Angola, and South Africa, will be highlighted and understood. This will inform 3 tailored solutions, with the application of remote sensing and GIS, to solve problems and build on opportunities unique to each country, in the sector of agriculture.

Countries of investigation: a method for showcase

Political definition

Brazil is the largest country in South America (by land and population), and the largest Portuguese-speaking country in the world, with an estimated population of 213 million, and a land area of roughly 8.4 million km^2 (population density of 25 /km^2 [4]. Angola is the 7th largest country in Africa (by land area), and the second-largest Portuguese country in the world (behind Brazil), with an estimated population of 33 million, and a land area of roughly 1.2 million km^2 (population density of 26/km^2). South Africa is the 9th largest country (by land area) in Africa, with an estimated population of 59 million, and a land area of roughly 1.2 million km^2 (population density of 49/km^2).

While, demographically speaking, Brazilians of European descent occupy more than half of the population group, Brazil plays host to the largest number of people of African origin, outside of Africa [5]. While Brazil occupies the most land area, it has a similar population density to that of Angola due to the large portion of unpopulated land occupied by the (declining) Amazon rainforest. South Africa and Angola have very similar land areas, but population density differs, with South Africa's population density almost more than double that of Angola's.

Pangea

In observation of the Pangea Map, it can see that the political borders of the eastern coastline used to be in contact with modern-day western Africa, with Rio de Janeiro (Brazil) near Luanda, the capital of Angola. Our modern understanding of political South Africa used to border Argentina on the eastern and western coastlines, respectively. This may explain why many similar geographical features across the South American and African continent are found, formed due to the separation of the Pangea supercontinent 200 million years ago, mostly evident in rift lines that shape the coast of modern-day Brazil and West Africa [6].

Understanding the ancient lay of continents can show, and explain similar geographical, and climatic conditions between countries, even if they now exist far apart on separate continents.

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[3] Excellent preliminary report written by Julio Herminio Bressan Martins (Brazil), Alexander Janse van Rensburg (South Africa) and Evandro Stefan Lima Barros (Angola).
[4] Worldometer, World Population, 2021, https://www.worldometers.info/world-population.
[5] Richard P. Momsen, Preston E. James, Brazil, Encyclopædia Britannica 2021, https://www.britannica.com/place/Brazil.
[6] Visual Capitalist, Nick Routley, 2020, Incredible Map of Pangea With Modern-Day Borders, https://www.visualcapitalist .com/incredible-map-of-pangea-with-modern-borders/.

Emerging economies

Brazil, Angola, and South Africa all can all fall under the definition of 'emerging economies', which can be defined as the "economy of a developing nation that is becoming more engaged with global markets as it grows" [7]. South Africa and Brazil are members of BRICS, which is an acronym "to indicate the emerging powers" [8]. Angola, while not defined as an emerging country in the traditional sense, has huge agricultural potential "with fertile soils, abundant water, and a favorable climate" [9], which may hold potential for economic growth.

The selected countries, all derived from different political, cultural, and historical backgrounds, will be showcase the wide-reaching potential for remote sensing in a GIS application.

Map of Pangea with modern day borders, by Massimo Pietrobon
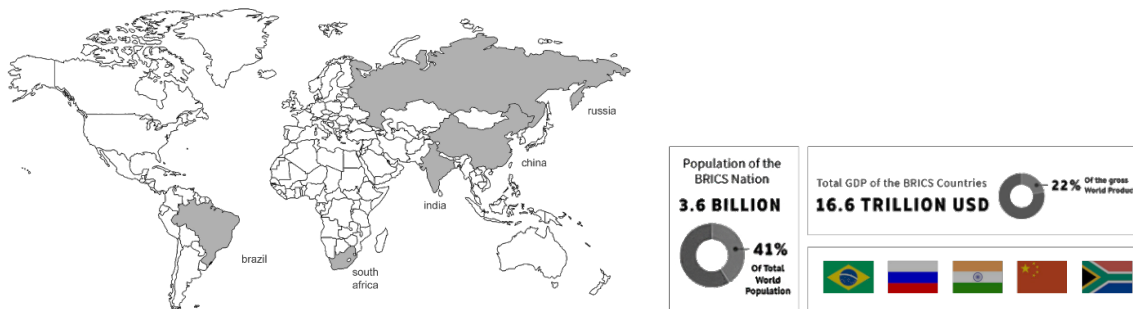
Angola - Aquifer Type and Productivity
- Unconsolidated - Variable (Low to High)
- Sedimentary Intergranular - Moderate to High
- Sedimentary Intergranular/Fracture - Moderate
- Volcanic - Low
- Sedimentary Fracture - Moderate (to High)
- Basement - Low (to Moderate)

BRAZIL
POPULATION 213 MILLION
LAND AREA 8.4 MILLION km²
DENSITY 25 /km²

ANGOLA
POPULATION 33 MILLION
LAND AREA 1.2 MILLION km²
DENSITY 26 /km²

SOUTH AFRICA
POPULATION 59 MILLION
LAND AREA 1.2 MILLION km²
DENSITY 49 /km²

0   125   250   500 km
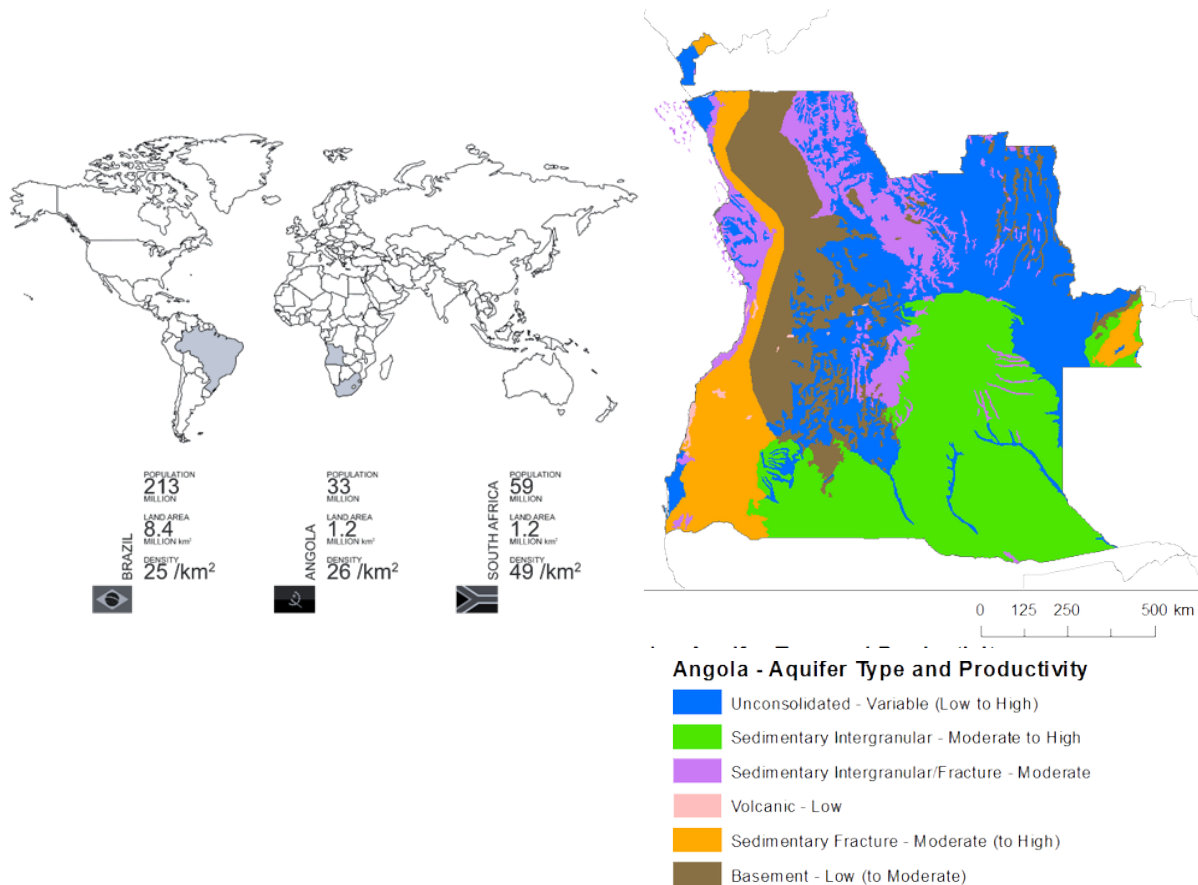
Motivation: the case for agriculture: potential for GIS application

Brazil is referred to as an "Agricultural Powerhouse", with the agricultural sector in the top 3 contributors to the Brazilian economy, existing in the top 4 producers of food in the world [10]. While agriculture is booming in Brazil, it is tainted by deforestation to make way for new land[7]. Brazil also faces productivity issues.

Forrest explains that "Of all pastures grown, Brazil currently only uses ⅓ of the productivity of its pastures". Forrest goes on to explain, that increased productivity may reduce the amount of deforestation for agricultural land, stating that:

"If it rises to a feasible 1/2, already reached by other developing countries, it would free up enough area to maintain agricultural expansion without further deforestation until 2040". In South Africa, while the COVID-19 pandemic caused stress and decline in most sectors, the Agricultural sector saw growth. Christo van de Rheede explains:

"The agricultural industry is the only sector within the South African economy that succeeded in recording positive growth figures during the Covid-19 lockdown. It deserves recognition for its ability to survive and make a positive contribution to the economy during this time" [11].

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[10] Forrest, Brazil as an Agricultural Powerhouse, 2019, https://www.weforest.org/newsroom/brazil-agricultural-powerhouse#:~:text=Agriculture%20is%20one%20of%20the, soy%2C%20sugarcane%20and %20maize).
[11] Biz Community, GDP statistics: Agriculture is the economy's backbone, 2020, https://www.bizcommunity.com/Article/196/358/208292.html.

While the resilience can be appreciated to external events, due to South African climate, agriculture is susceptible to water shortages and irregular rainfall. Better water management and smart water-wise systems may be the key to unlocking South Africa's water potential.

Angola, while having "tremendous agriculture potential", still imports most of its food, and as 58 million hectares of unused land for agricultural activity [12]. The agricultural holdings are mainly subsistence-based, and small in scale. The agricultural landscape may be minimal as of now but should increase due to landmine clearance as a result of the civil war[9].

The management, grouping, documenting, and using of shared resources and agricultural infrastructures may be useful in unlocking this potential. GIS has been widely used as a tool for increasing Agricultural potential across the globe. Shimonti Paul explains that:

"The future growth in agriculture must come from new technologies which are not only cost-effective but also in conformity with natural climatic regime of the country; technologies relevant to rain-fed areas specifically; continued genetic improvements for better seeds and yields; data improvements for better research, better results, and sustainable planning; bridging the gap between knowledge and practice; and judicious land use resource surveys, efficient management practices and sustainable use of natural resources" [13].

Going on to explain that, "GIS tools and online web resources are helping farmers to conduct crop forecasting and manage their agriculture production by utilizing multispectral imagery collected by satellites".

With regards to our countries of focus, the potential for GIS application is identified in the agricultural sector, with solutions to the country-specific problems below:

- ❑ Brazil – *Problem*: Deforestation due to agricultural land demands. Low productivity rates in pastures. Solution: Increase the productivity of current land to slow down the deforestation rate.
- ❑ South Africa – *Problem*: Water shortages due to arid climatic conditions. Irregular rainfall. *Solution*: Sophisticated water management and soil monitoring, smart irrigation, understanding water consumption of plant types.
- ❑ Angola – *Problem*: Underused fertile land. Suffers productivity due to small-scale allotments. *Solution*: Organizing of documenting of smallholdings, introducing large-scale allotments with shared agricultural resources, formalized irrigation management.

Definition of GIS

GIS is defined as Geographical / Geospatial Information System / Science / Studies as it is a framework for gathering, analysing and managing data. Its aim is to allow an efficient understanding or study of "What, Where and When" on the earth´s surface. NCGIA, in 1987 described GIS as a computerized database management system for the capture, storage, retrieval, analysis and display of spatial data. The uses of GIS go far and beyond when it comes to analysing entities on the earth´s surface, however, in this the focus is finalized on its use in agriculture. In the Agricultural Area, GIS is usually mostly used for Zoning, Monitoring Environmental Risks, Management of Watersheds, Floodplains, Groundwater modeling and tracking.

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[12] International Trade Administration, Angola – Agricultural Equipment, 2019, https://www.trade.gov/knowledge-product/angola-agricultural-uipment#:~:text=Currently%2C%20Angola's%20main%20agricultural%20crops,in%20the%20highlands%20and%20valleys.
[13] Shimonti Paul, Geo spatial World, How GIS is enabling the agricultural sector, 2019, https://www.geospatialworld.net/blogs/gis-in-agriculture/.

The Base Knowledge for GIS consists on:

❑ Computer Science: Graphics, Visualization, System Administration;
❑ Application Area: Planning, Geology, Forestry, Marketing, Site Selection, etc.;
❑ Geography and Related: Cartography, Geodesy, Spatial, Landforms, Photogrammetry, etc.

In order to be able to manage such data, the data first needs to be gathered and to input such data in GIS, Geographic Information Technologies such as Global Positioning System (GPS) and Remote Sensing (RS) are used.

Definition; inputs; outputs; circular flow
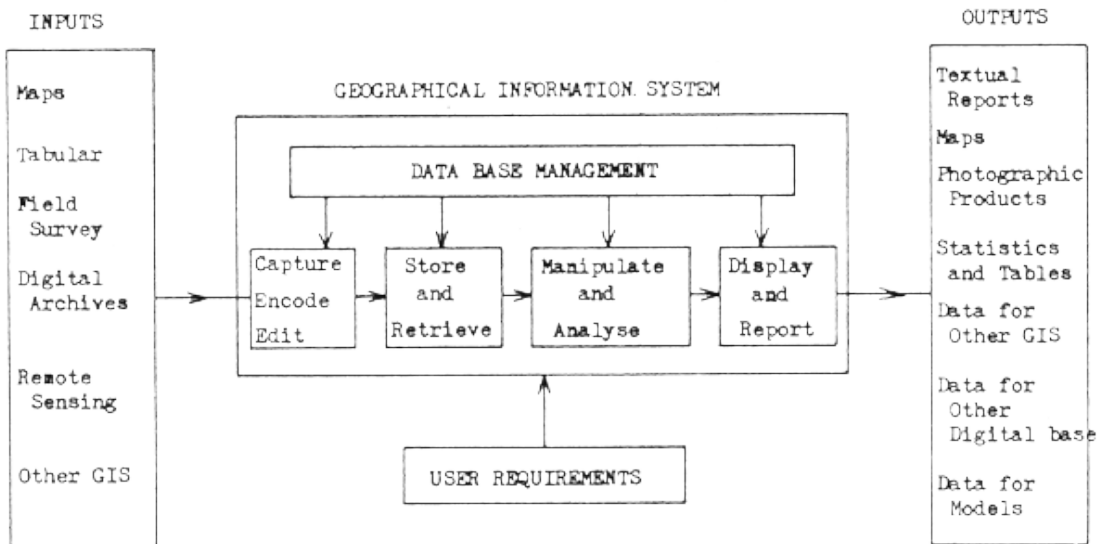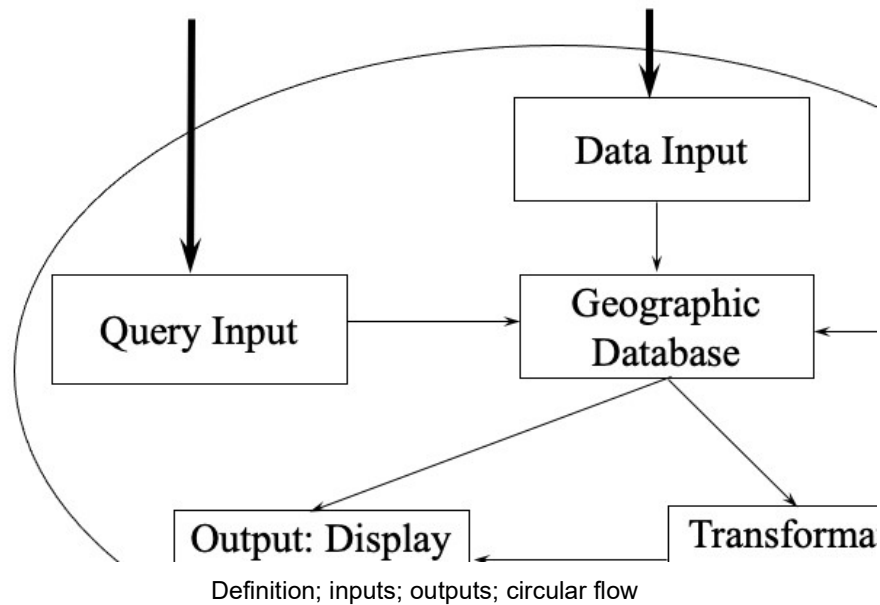
Mind Map for the processes of GIS starting by the collection of data till the final visual output

GIS IN THE PLANNING PROCESS
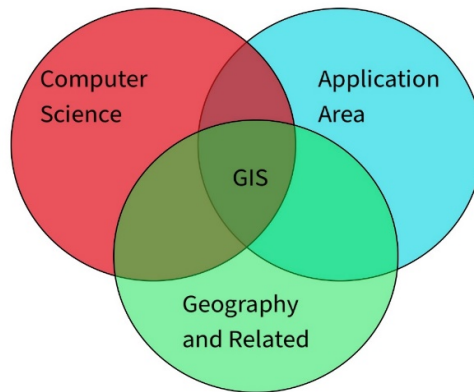
Illustration for the Basic Knowledge Needed to Work with GIS
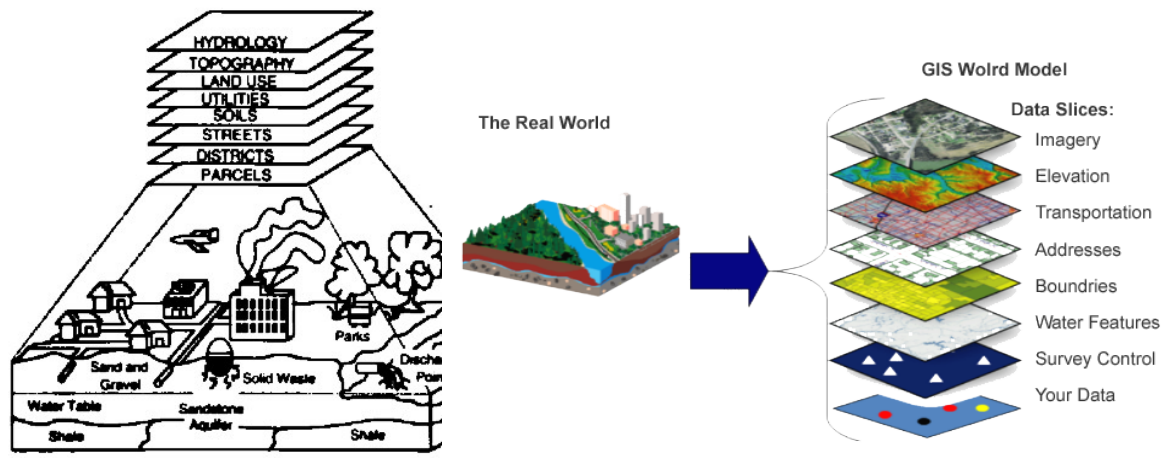
The many different layers found in a GIS file to represent the different elements in the earth´s surface in a 2D

The GIS way of Modeling data

The whole aim of GIS is to be able to represent 3D world situations in a 2D map that can be analysed and managed. This allows geographical features in the real world to be digitally stored and represented in a 2D Map in Analog form.

The Data in GIS is mainly interrelated with their geographical location as each element has an explicit location on the earth´s surface, and such elements are organized by layers or themes and each layer represents a common feature in the real world.
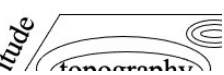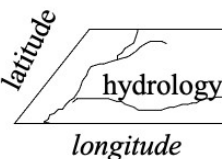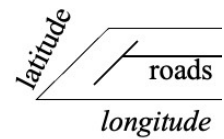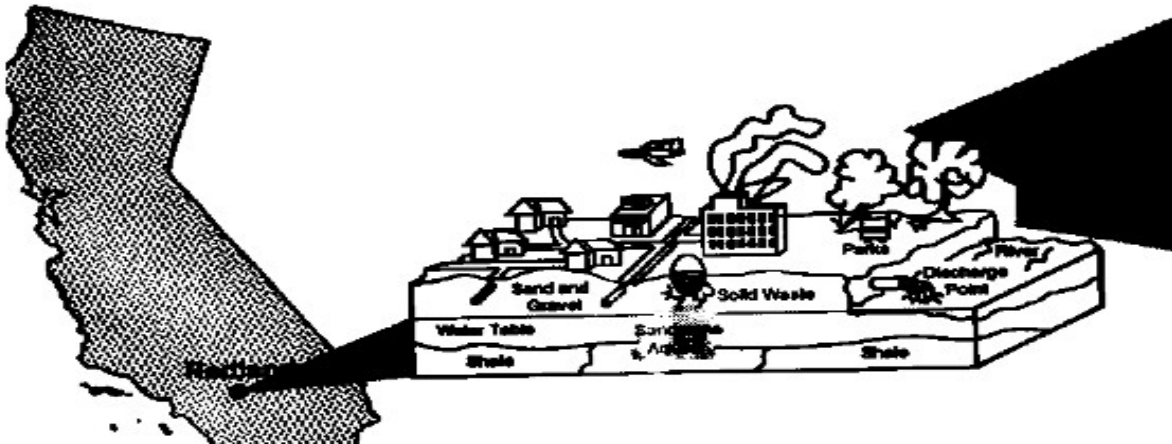
Each layer in GIS is associated with a certain type of feature or theme, which one can afterwards add attributes to each element

After specifying the layers, it is important to understand the information or data inside those layers. GIS comprises data in two ways, Spatial Data and Attribute Data. All this organizing and data managing is finally represented in two ways, Vector Format which is known to be the most precise, and Raster Format to be the easiest.

All Geographical Data has four properties:

❑ projection: the method which the curved 3D surface of the Earth is represented in 2D;
❑ scale: the ratio of distance on map to the equivalent on ground;
❑ accuracy: how well does the database info and the real world match;
❑ resolution: the size of the smallest feature able to be recognized.

Concept of Vector and Raster

Raster Representation

	0	1	2	3	4	5	6	7	8	9
0							R	T		
1						R			T	
2		H				R				
3						R				
4				R	R					
5			R							
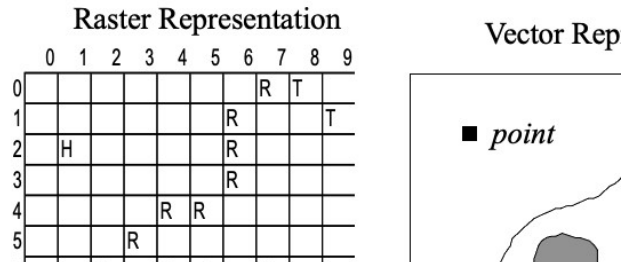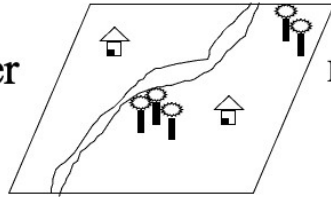
Vector Rep

■ *point*

The Raster representation consists of pixels while a Vector Representation is made of points, lines and areas

State of the Arts

As food and agricultural demand keep growing, and given the limited availability of productive land, there is a latent need to increase the agricultural intensification in the World.

After the Green Revolution, with the improvement of crop varieties and use of fertilizers, pesticides, and irrigation, the advances in productivity in today's World point out to the use of cutting-edge technologies already employed in the Fourth Industrial Revolution. Precision agriculture (PA), thus, was born as a need to produce more using less land and more efficient processes.

The enhancement of the agricultural productivity is only possible due to the deployment of techniques in information and communication technologies, such as remote sensing, global positioning systems (GPS), geographic information systems (GIS), Internet of Things (IoT), Big Data analysis and artificial intelligence (AI). The use of remote sensing in agriculture will be the focus in this section, making possible to link the content of the Spatial Analysis course with the enhancement of sustainable agricultural production in Angola, Brazil and South Africa and the consequent impacts in the preservation of their natural resources.

Remote Sensing

The classification of remote sensing systems in agriculture are based on two criteria: (i) the sensor platform and (ii) the type of sensor. Sensors are normally inserted on satellites, aerial, and on-surface platforms. Satellite sensors haven been used since the 70s, but due to precision considerations, have been complemented with aerial platforms, such as aircraft and unmanned aerial vehicles (UAVs), that allow better data caption and diverse range of bands (Rajendra P. Sishodia, 2020).

On-surface platforms, on the other hand, are also known as proximal remote sensing, and can be classified in 3 types: (i) hand-held, (ii) free-standing in the field, and (iii) mounted on tractor or farm machinery (Rajendra P. Sishodia, 2020). Sensors can differ based on four types of resolution they offer:

❑ Spatial resolution means the size of the pixel that represents a certain area on the floor.
❑ Temporal resolution is a matter of the sensor platforms and it indicates the time this device takes to "revisit" the same observation area.

- Spectral resolution indicates the number of bands in electromagnetic range that a sensor can capture.
- Radiometric resolution that stands for the sensor's capacity to differentiate grey-scale values.
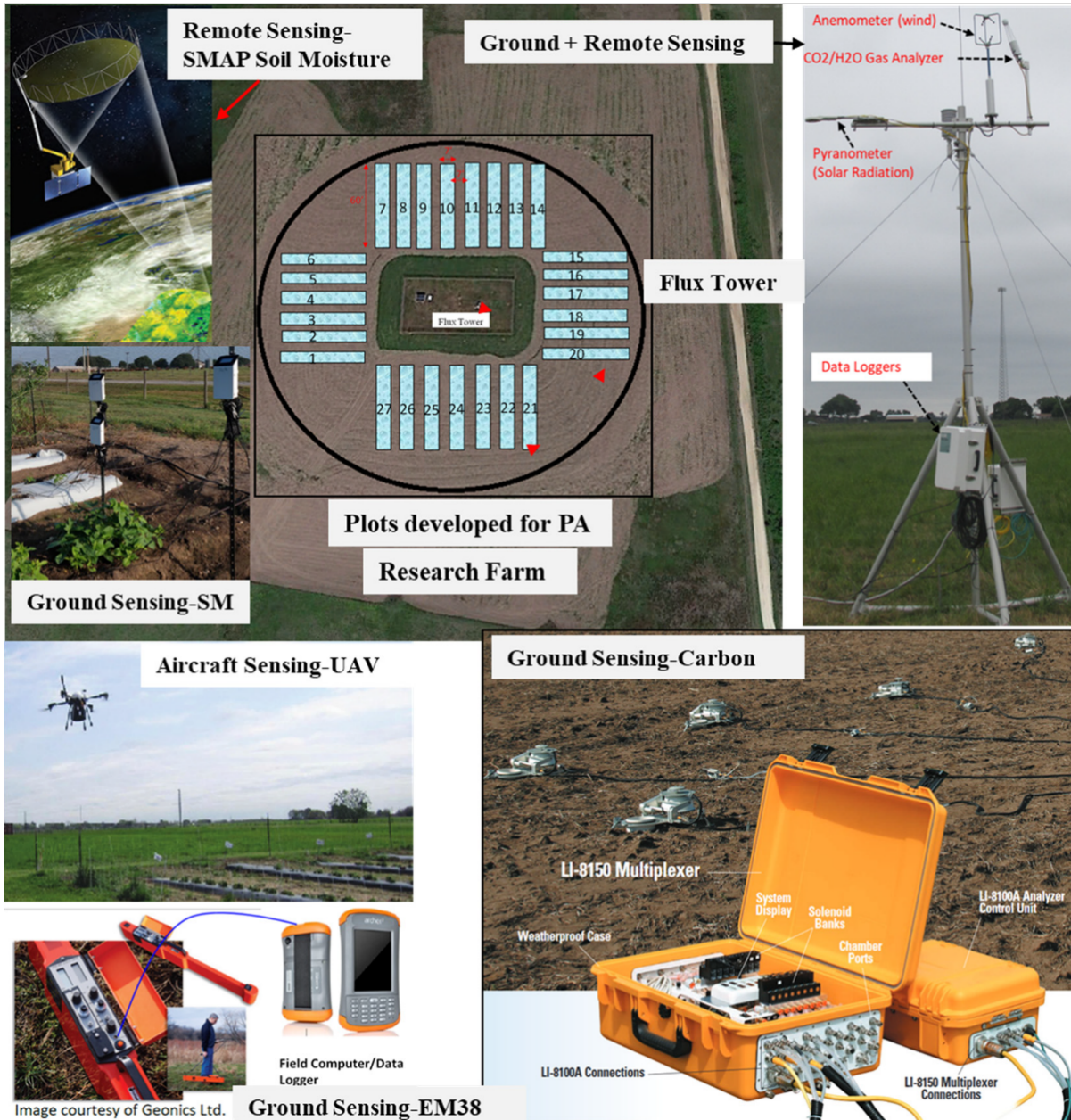
A typical layout for the remote, aircraft, and ground sensing systems employed for precision agriculture. SMAP = Soil Moisture Active Passive; PA = Precision Agriculture; SM = Soil Moisture

Even though recent satellites offer high spatial and temporal resolution (<5m and daily), PA applications require a range of precisions. Crop biomass and yield estimation need spatial resolution between 1-3m, fertilizing and irrigation between 5-10m and weed mapping and herbicide application a fine resolution of 5-50cm. Thus, for many agricultural applications, aerial platforms, such as UAVs, and other ground-based platforms are needed to offer flexibility in providing fine spatial and temporal resolution. These devices can have proximity sensors that provide more accurate vegetation indexes, used for crop nutrient assessment.

Other sensors present in satellites, as thermal infrared, and microwave, can also help in estimating the energy emitted at the crops and consequently its water stress, evapotranspiration (ET), and irrigation requirements. Microwave sensors can be helpful to estimate large areas soil moisture and crop water use and have the advantage to penetrate clouds. Nevertheless, the rough spatial resolution limits the use of these sensors, despite the methods developed to downscale their resolution (Rajendra P. Sishodia, 2020).

Applications

The applications of remote sensing in Precision Agriculture are mainly of five types.

Irrigation Water Management

Conventional irrigation practices do not consider the variability within a field, and waste resources applying an uniform irrigation over the same field. Remote sensing data help to map how the terrain differs and allows applying variable rates of irrigation for a given field. Capturing indicators such as ET, soil moisture and crop water stress, it is possible to estimate better water requirements and to schedule irrigation more precisely (Rajendra P. Sishodia, 2020). This can help mitigate water stress, what is absolutely relevant in the case of South Africa.
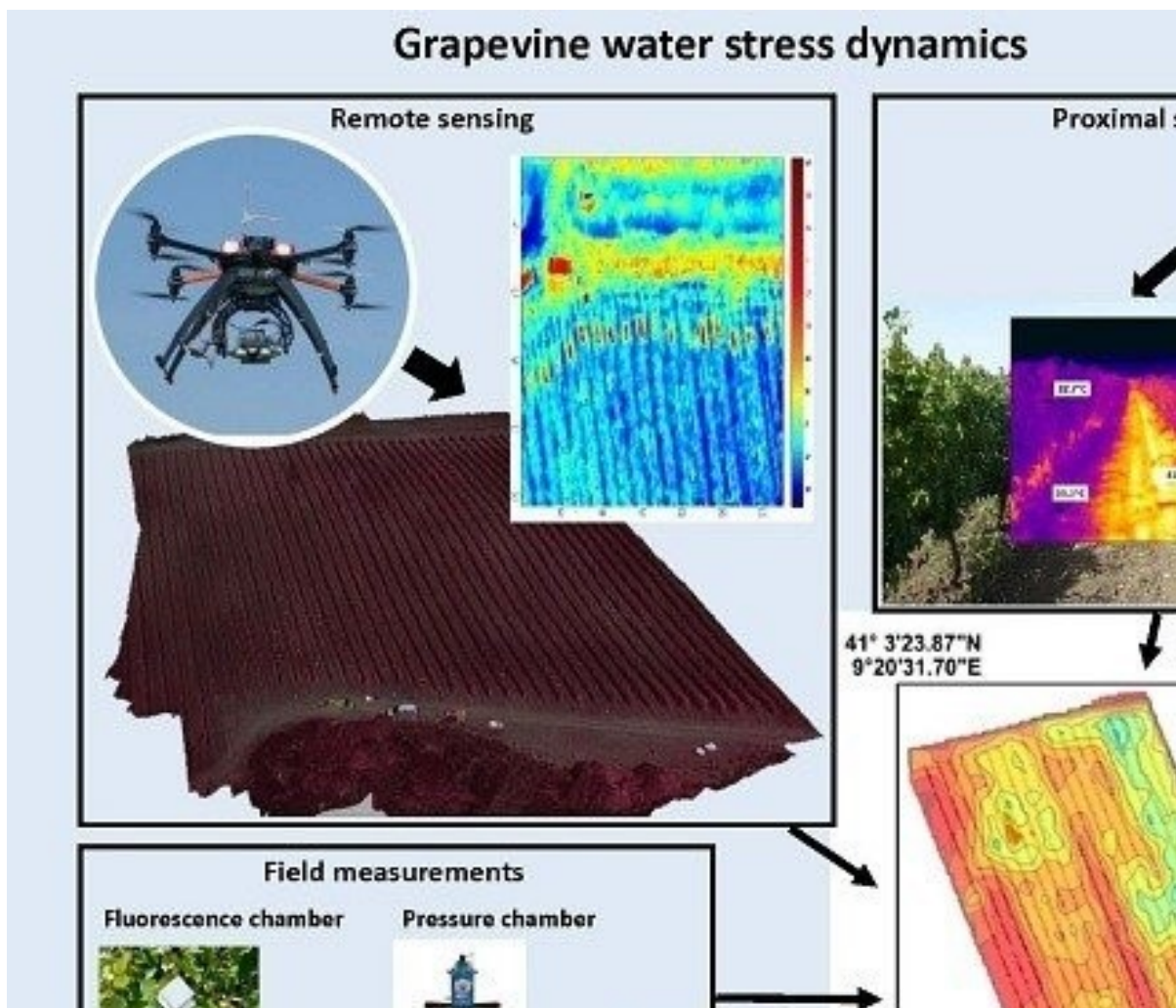
Nutrient management

Normally the application of fertilizers occurs uniformly. Nevertheless, the fertilizer requirements differ along time and irregularities in the field. Mapping this variability would be very challenging using traditional tools. Using vegetation indices (e.g. normalized difference vegetation index – NDVI, and Soil adjusted vegetation index – SAVI), obtained by remote sensing data, can be significantly related to plant productivity. Mapping these parameters can assist spatial variability in crop nutrient status. These data could be obtained using sensors mounted on tractors that measure the reflectance of the crop and link it to GIS data. Having this information helps to have more productive crops and spending less with fertilizers (Rajendra P. Sishodia, 2020). The application of this methodology could increase the productivity in the case of soy beam crops in Brazil, helping to decrease the speed of deforestation in the Amazon region, and in Angola's case, raising the fertility of the soil.
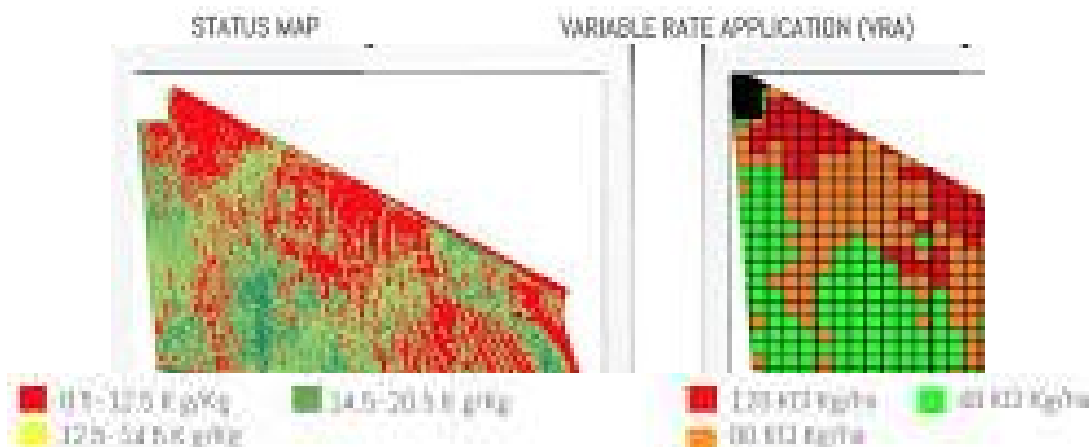
Disease Management

The conventional method of field scouting, used for disease detection, is time consuming, labor intensive and susceptible to human mistakes. Remote sensing can be used to monitor diseases efficiently, through techniques using RBG, multi-spectral, hyperspectral, thermal and fluorescence imaging to recognize diseases in different types of crops (Rajendra P. Sishodia, 2020). This technique could be specially applied in Brazil and Angola cases, where, due to tropical climate, there is a wider range of diseases that affect crops and preventing them would generate gains in productivity and diminish the need for new.
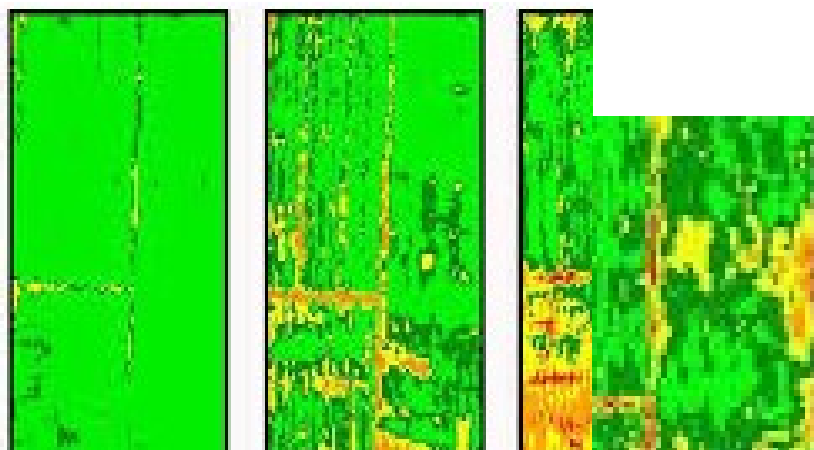
Weed management

Uniform application herbicides showed to be a very inefficient practice. Weeds can be recognized from crop through their specific spectral signature related to the phenological or morphological attributes. Mapping weed patches can help to identify concentration spots and apply herbicide quantities according to the need, reducing losses and impact on the environment, especially regarding water bodies' poisoning. This is of great importance to maintain the quality of scarce water, especially in South Africa.
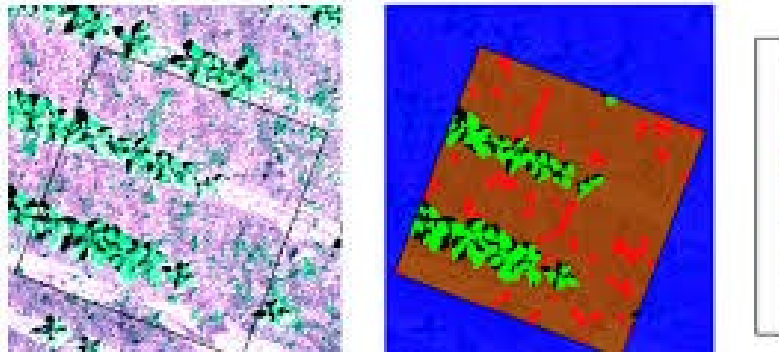
Crop monitoring and yield

Monitoring crop and yield are fundamental to understand the crop's response to environmental and agronomic practices. Leaf area index (LAI) and biomass are two essential indicators to measure crop's health, but their in-situ collection is time consuming, destructive and do not provide spatial variability. Remote sensing data on crop growth can help collecting information on site-specific properties, management, and stressors, through hyperspectral images using machine learning and classifications to map tillage and crop residue in fields (Rajendra P. Sishodia, 2020). This is of major importance for the three cases studied here once it faces more general crop's troubles.
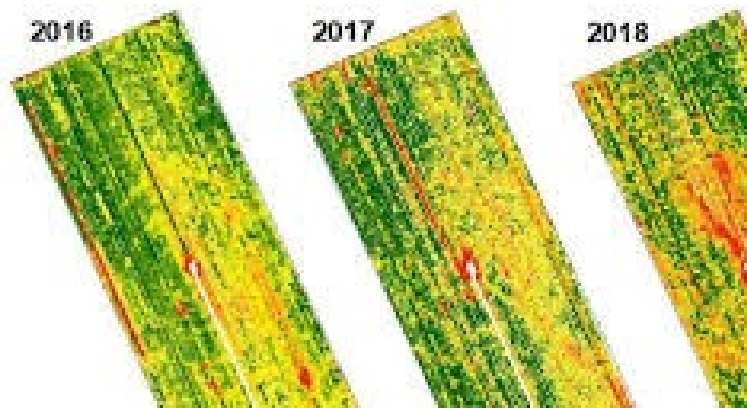
Applications of GIS and Remote Sensing

Understanding deforestation in Brazil

Brazil: deforestation in the soy-beam frontier at Mato Grosso State - Using Remote sensing data to determine the soybean agricultural frontier in Mato Grosso State.

Brazil is known in history for having economic cycles that led to the exploration of its "wild" territories in its countryside, related to the exploitation of natural resources, such as pau-brasil log, sugar plant, gold, coffee and rubber. The most recent and still on-going process is the agricultural cultivation of soy-beam, that, since at least the 70's, is the last Brazilian economic cycle, linked, at first, with the governmental incentives for the Amazonian region occupation during the Brazilian Military Dictatorship, bringing Capitalized farmers and private companies to the region. (Arvor, Dubreuil, Simões, & Bégué, 2013).

This exploration defined an "arc of deforestation", know as the Amazonian pioneer frontier. This deforestation process is especially accentuated on the Mato Grosso State, a State in the Legal Amazon which represents the border of this biome with the Brazilian Savana ("Cerrado") and Pantanal (frequently flooded lands). Arvor et al. (2013) produced an adapted evolution of the pioneer frontier, for the case of soybean expansion in Mato Grosso.
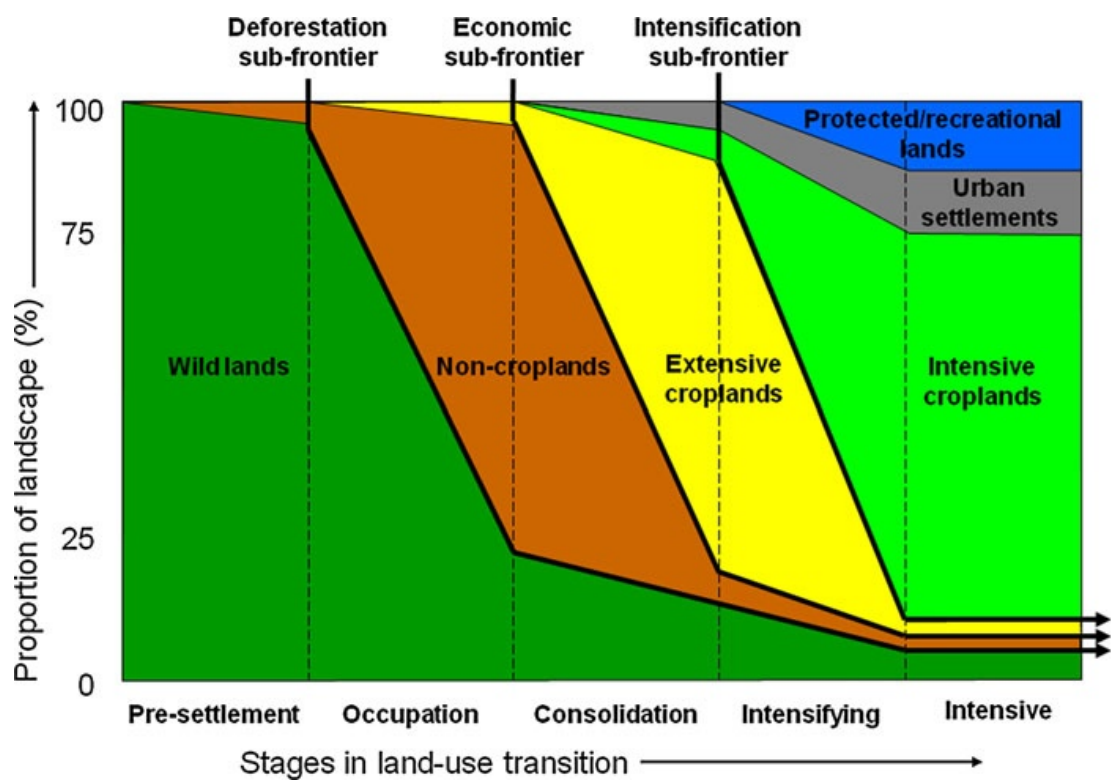
Stages of the evolution of the pioneer frontier and the corresponding land-use types adapted to the case of soybean expansion in Mato Grosso. Source: Arvor et al. (2013)

The aim is devoted at looking at this State to understand how remote sensing can monitor the deforestation at this region, classifying its different shades, and discuss how the use of this technique could increase the productivity of the already in-use land and avoid further deforestation.

Using remote sensing techniques to map land-use and spatio-temporal dynamics

Using two sources of deforestation maps from Landsat images, Arvor et al. (2013) produced agricultural expansion maps, discriminating croplands from other vegetation covers using vegetation indexes as EVI (Enhanced Vegetation Index) and NDVI (Normalized Difference Vegetation Index), with a spation resolution of 250m and temporal resolution of 16 days.

Therefore in Brazil, Remote Sensing can lead a transformation in precision agriculture, so that the intensification of the productions, and consequent increase in productivity, will help mitigating the deforestation of the Amazon forest. That is especially true when how the exploitation of new fields occur is considered, and how a major part of the land is not being occupied by agricultural intensive practices.
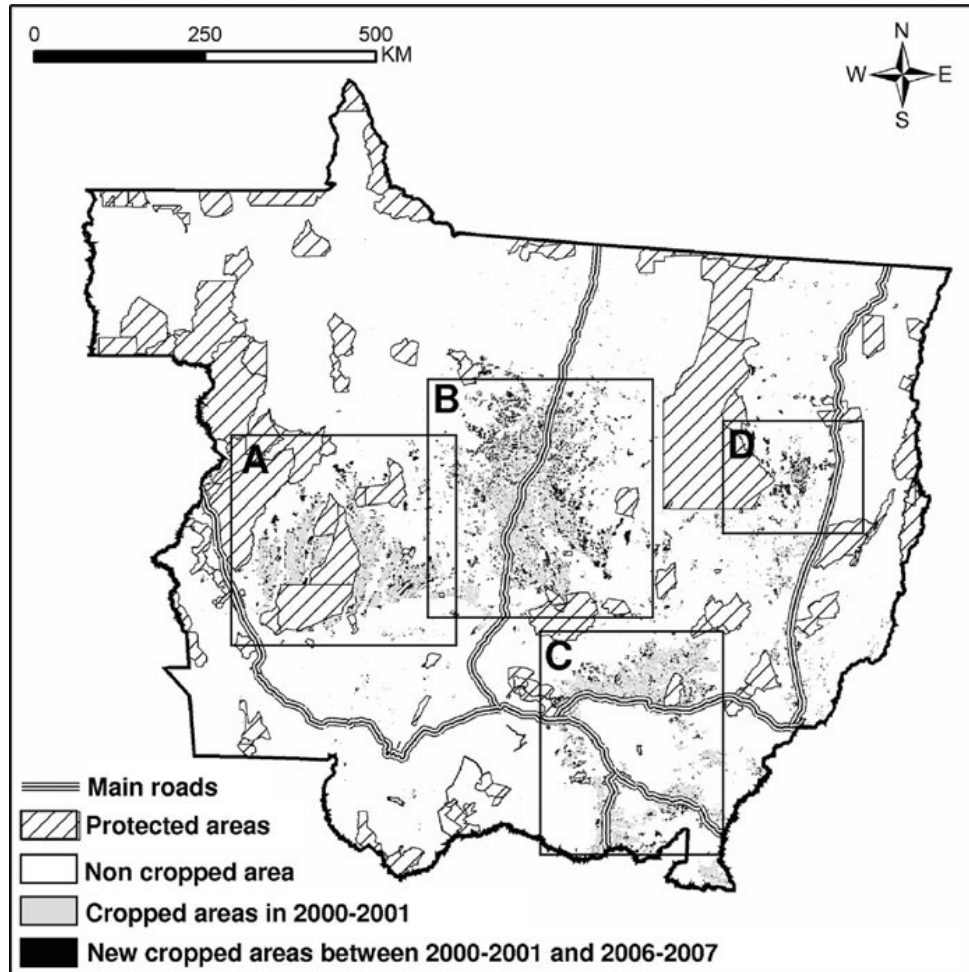
Agricultural expansion in Mato Grosso. The four main agricultural regions are:
A western, B central, C southeastern, D earstern regions. Source: D. Arvor et al. (2013)

Using remote sensing for mapping the soybean agricultural frontier

Identifying a spatial scale, indices to monitor the sub-frontiers and a rule-based model for applying it, Arvor et al. (2013) mapped the "deforestation", the "economic" and the "intensification" sub-frontiers a grid of 27.75 x 27.75 km pixel size. After doing that, they calculated the percentage of landscape represented by main land-use types and estimated the evolution stage of each agrarian locality. Afterwards, they split the analysis into cropland and non-cropland areas and determined the stages of the agricultural frontier.

It is interesting to notice already how the decreasing of wild forest could be mitigated if the intensive use of croplands were higher. It is also important to notice that the authors (Arvor, Dubreuil, Simões, & Bégué, 2013) considered as intensive use simple techniques in agriculture, as rotation of crops. It is, thus, to imagine that, if remote sensing techniques for precision agriculture were used in these fields, the productivity would be even higher and the need to keep deforesting would be even lower.
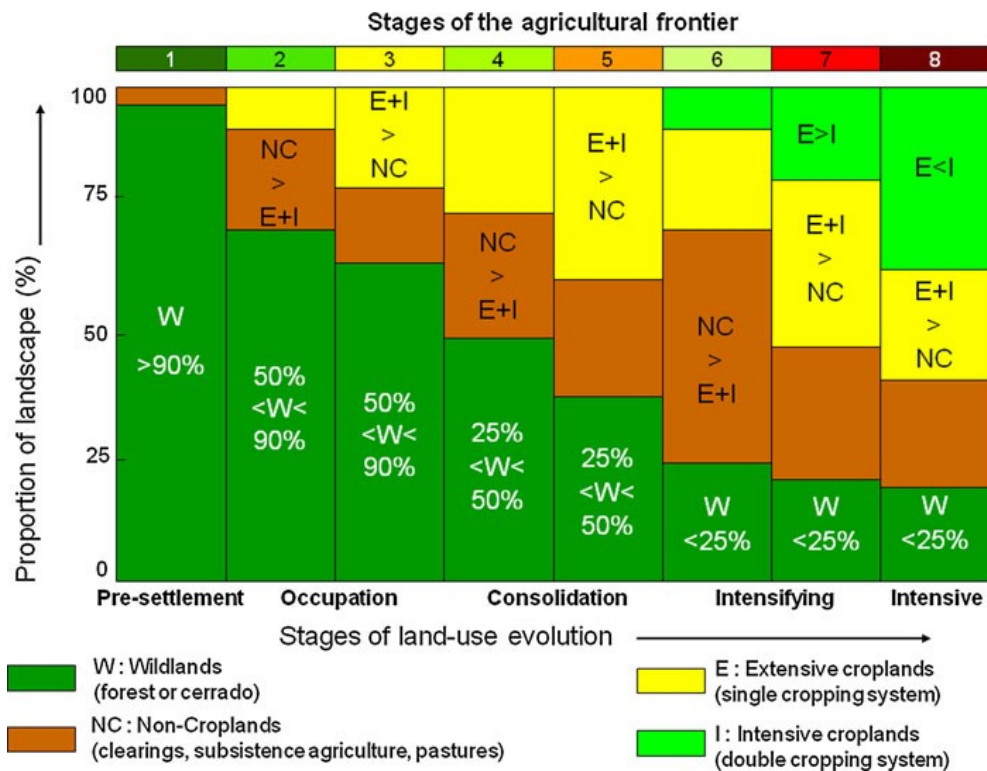
Rules to adapt the frontier model for mapping the soybean agricultural frontier based on remote sensing data. Source: Arvor et al. (2013)

Monitoring the frontiers obtained (as shown in the following four figures).

❑ Deforestation sub-frontier: these maps show that the southern region of Mato Grosso is the most affected by deforestation. Nevertheless, the temporal comparison shows that the deforestation sub-frontier moved northwards, in direction to the Amazon forest.

❑ Economic sub-frontier: the evolution between 2000-2001 and 2006-2007 shown in **Errore. L'origine riferimento non è stata trovata.**, points out that the two main regions (central region and western region) are marching in direction to each other and will probably meet soon.

❑ Intensification sub-frontier: in 2000-2001, double cropping systems (interpreted as intensification) did not represent the major part of the cultivated areas. On the other hand, in 2006-2007, double cropping systems are being applied in the main agricultural regions (central, western, and south-eastern regions). It is important to stress out that this only mean basic intensification of the use of the land, and better productivity could be certainly achieved employing remote sensing techniques applied to agriculture.

❑ Soybean agricultural frontier: the soybean agricultural frontier confirms that deforestation in Mato Grosso is still going on and reaches more than 50% of localities' areas in many places (Arvor, Dubreuil, Simões, & Bégué, 2013). Three main regions (central, western and south-eastern) are recognized as large-scale agriculture areas. The central region along road BR- 163 experienced the biggest changes. Thus, the consolidation of its croplands was the main driver of deforestation in the region.

These four maps confirm that Mato Grosso is in a very active colonization process that drives the advance of the soybean frontier (Arvor, Dubreuil, Simões, & Bégué, 2013).
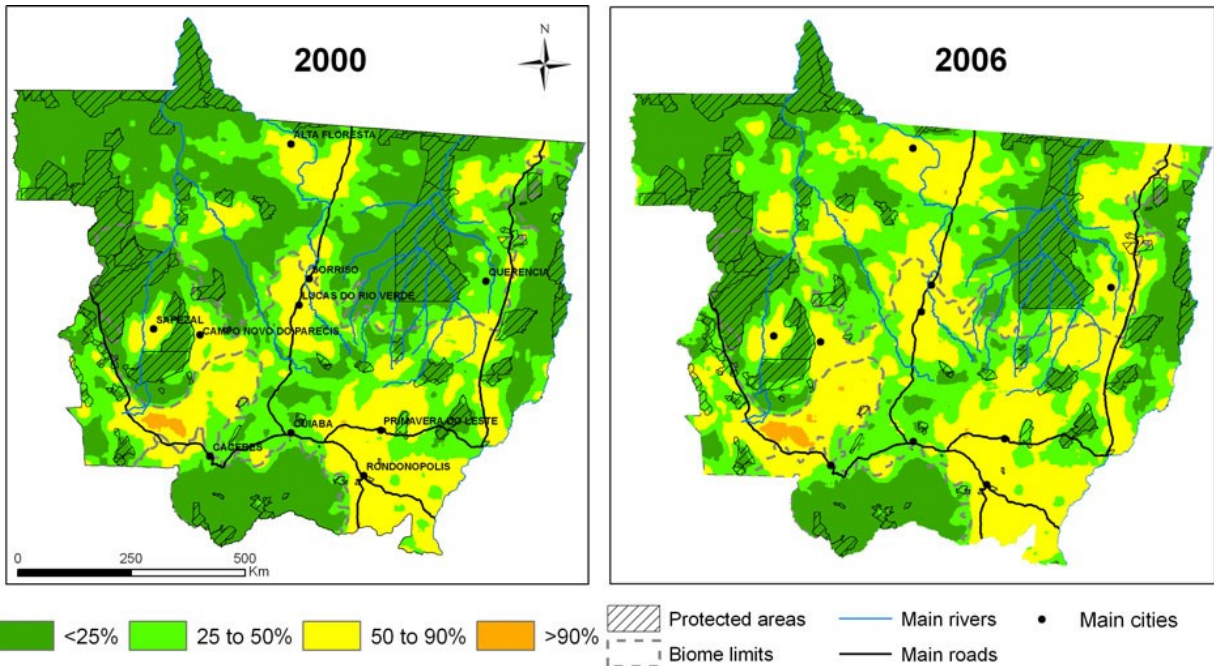
Evolution of the ''deforestation sub-frontier'' in Mato Grosso between 2000 and 2006 based
on the DEF index: percentage of deforested area per area of 0.25º x 0.25º. Source: Arvor et al.(2013)
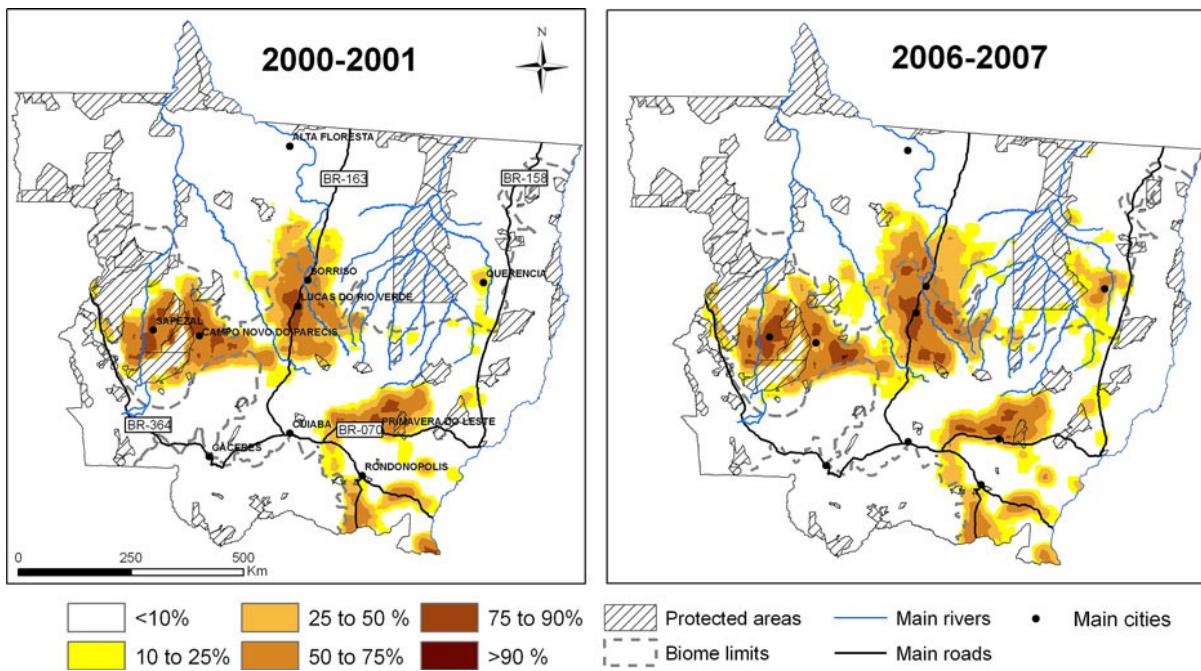
Evolution of the ''economic sub-frontier'' in Mato Grosso between 2000 and 2006 based on the ECO index:
percentage of extensive cropped area as compared to the deforested area (class\10 %
also includes non-deforested areas). Source: Arbor (2013)

Since Agriculture is used for national and international use, this sector is sometimes overlooked. Agriculture
at the end like everything else depends and its highly influenced by education levels in the area and
finances, therefore, Remote Sensing must be used not only to directly impact these sectors, but also to study
the different educational levels in the country as well as economic wealth.
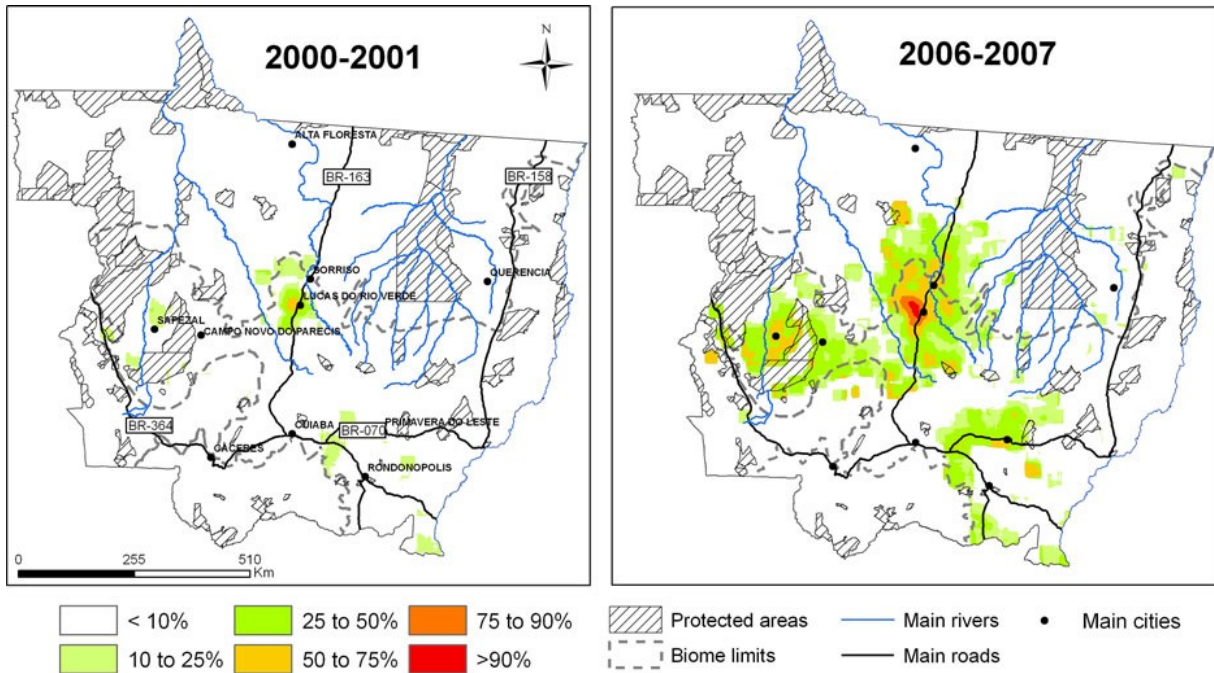
Evolution of the "intensification sub-frontier" in Mato Grosso between 2000 and 2006 based on the INT index: percentage of cropped area with double cropping system as compared to the total cropped area (class 10 % also includes non-deforested areas). Source: Arvor et al. (2013)
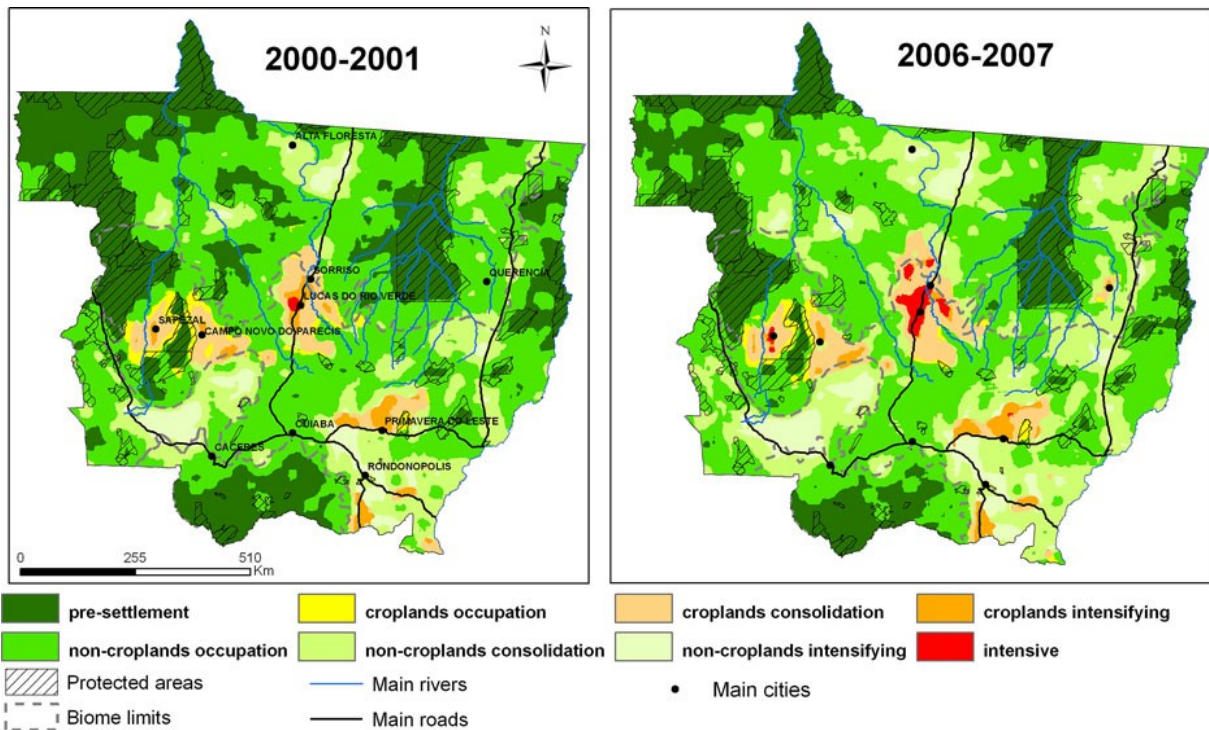
Map of the evolution of the soybean agricultural frontier in Mato Grosso between 2000–2001 and 2006–2007 according to the land-use transition stages proposed. Source: Arvor et. al (2013)

Understanding Water Scarcity in South Africa

According to Water Research Commission (WRC), South Africa is defined as a country with water scarcity.

The Food and Agricultural Organisation (FAO) "estimated that 65% of SA does not receive enough rain to

support successful dryland agriculture" [12]. It is also estimated that the agricultural sector in South Africa is responsible for most water consumption (between 51% and 63%)[12]. It is also believed that 98% of South Africa's water resources have already been allocated, which will not be able to cope with the increasing population and food needs [14].

A reassessment of the current methods for water management and use needs is needed. When it is taken into account the "added pressures of climate change, population growth and decline in water quality due to for salinization, the need for improved assessments of the current water resources and land uses is critical".

GIS and Remote Sensing: Water management

Remote sensing can relay vital water-related data to policymakers, managers, consultants, researchers, and the public[15]. Mohamed Taher Sassi explains that "Remote sensing, with varying degrees of accuracy, has been able to provide information on land use, irrigated area, crop type, biomass development, crop yield, crop water requirements, crop evapotranspiration, salinity, waterlogging and river runoff"[13]. When this data is combined and integrated into a GIS system, it can be useful for management, planning and evaluation.

There are many advantages of Remote sensing over traditional field measurements, namely objectivity; synthetic means of collection that allows for time comparisons between data and the spatial representation of data[13]. With specific regard to irrigation, remote sensing can monitor soil wetness (field wetness indicators) and make subtle changes throughout the irrigation cycle based on specific data on evaporation and moisture.

Application of Remote sensing to South Africa

The Water Research Commission underlines that the future of agricultural water management and research lies in the utilization of Remote Sensing. Some examples of these technologies include for water include:

❑ field wetness indicators;
❑ drone Multispectral Cameras (Irrigation Drone);
❑ satellite (NVDI, albedo, surface temperature, cloud cover, etc.);
❑ weather station data.

Example: Integrated Area map of South Africa, using Remote Sensing and machine learning (2018)

A paper titled *AN EARTH OBSERVATION APPROACH TOWARDS MAPPING IRRIGATED AREAS AND QUANTIFYING WATER USE BY IRRIGATED CROPS IN SOUTH AFRICA,* by the Water Research Commission and the Department of Agriculture, Forestry and Fisheries aimed to "update the existing estimates of the amount of water used by irrigated agriculture in South Africa [16].

This investigation combined remote sensing data from Satellite, Weather stations, and Thematic resources, to produce an incredibly accurate indication of the weather, evaporation, and irrigation system in South Africa. This raw data was inputted into a GIS application and by using machine-based learning (based on small-scale fieldwork), a 95% accuracy was obtained.

[14] Van Niekerk, Alvin, Caren Jarmain, and R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018.

[15] Mohamed Taher Sassi, 2014, GIS and RS Application in Water Management in Agriculture Fields, Munich, GRIN Verlag.

[16] Van Niekerk, Alvin, Caren Jarmain, and R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018.

Various data was then able to be extracted from the model, to provide various maps relating to *Irrigated vs. Rainfed Areas* (fig 10, fig 11)); *Evapo-transipitation* (fig 12); Crop vs rainfall and irrigated tabular data (fig 13) and *River flow rates and times* (fig 14), to name a few.
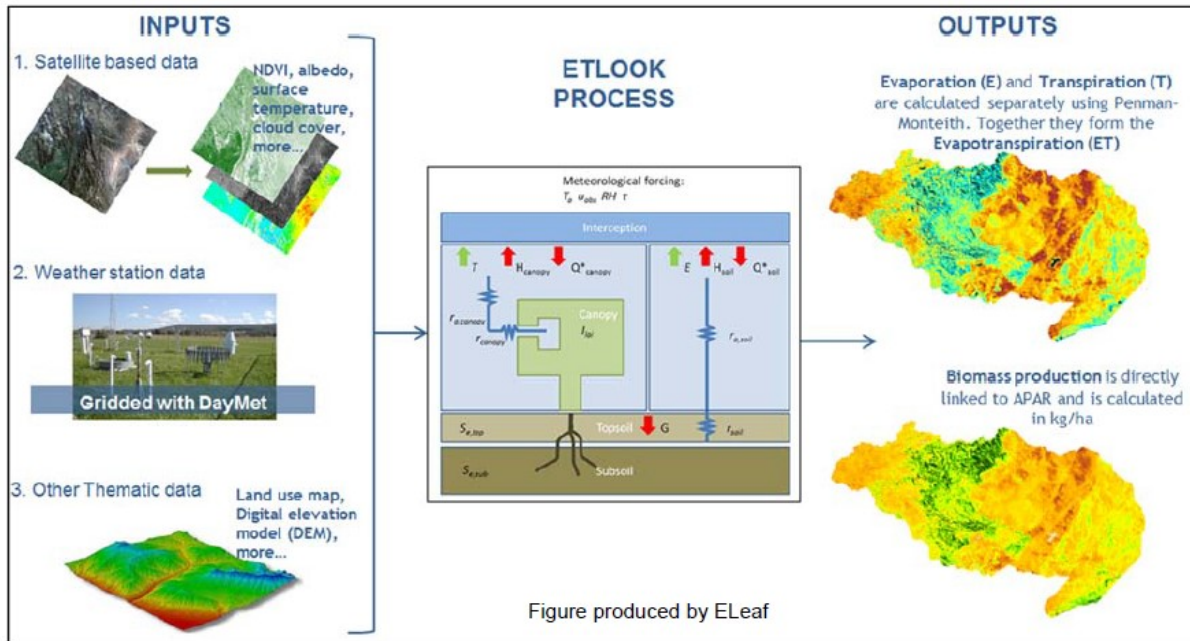
Schematic representation of the ETLook process applied to produce the ET datasets. ref: Van Niekerk, Alvin, Caren Jarmain, and R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018
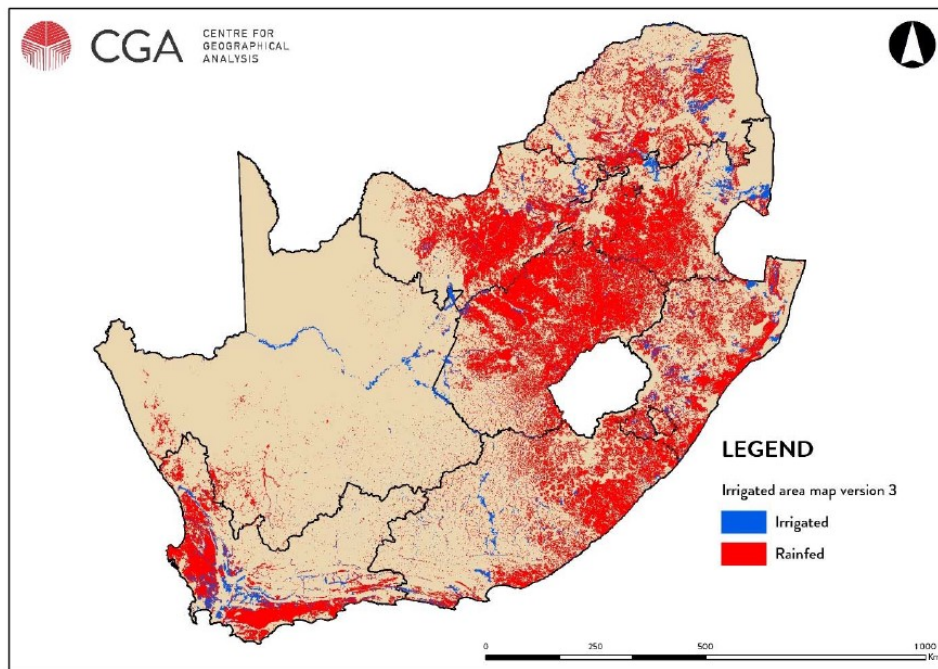
Version 3 of the IAM. ref: Van Niekerk, Alvin, Caren Jarmain, and R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018
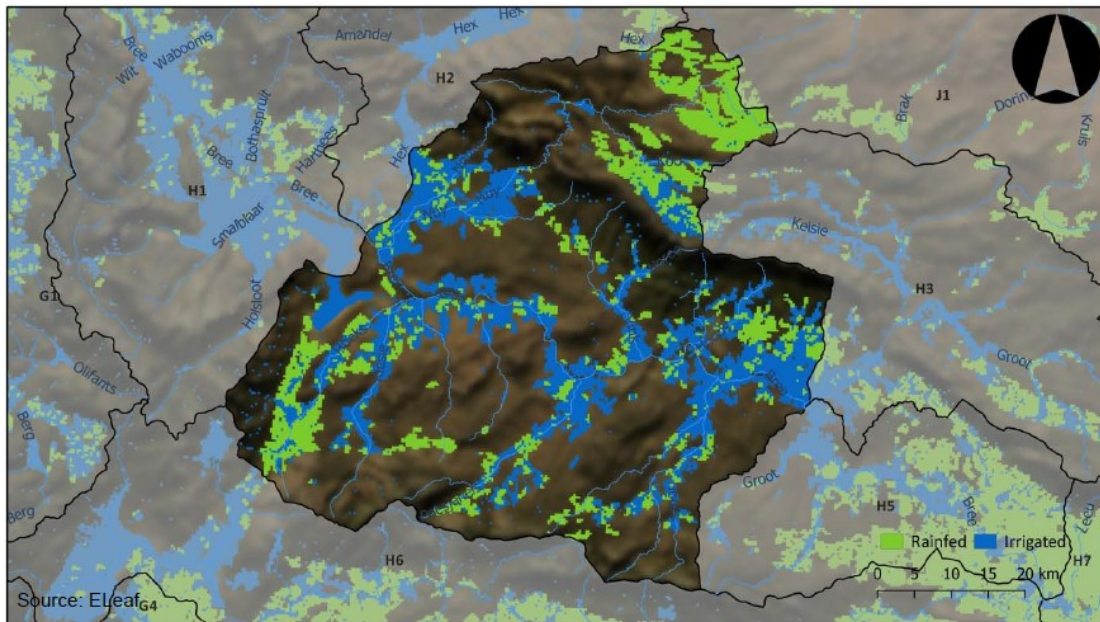
The extent of rainfed (green) and irrigated agricultural areas (blue) within secondary catchment H4. Ref: Van Niekerk, Alvin, Caren Jarmain, R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018
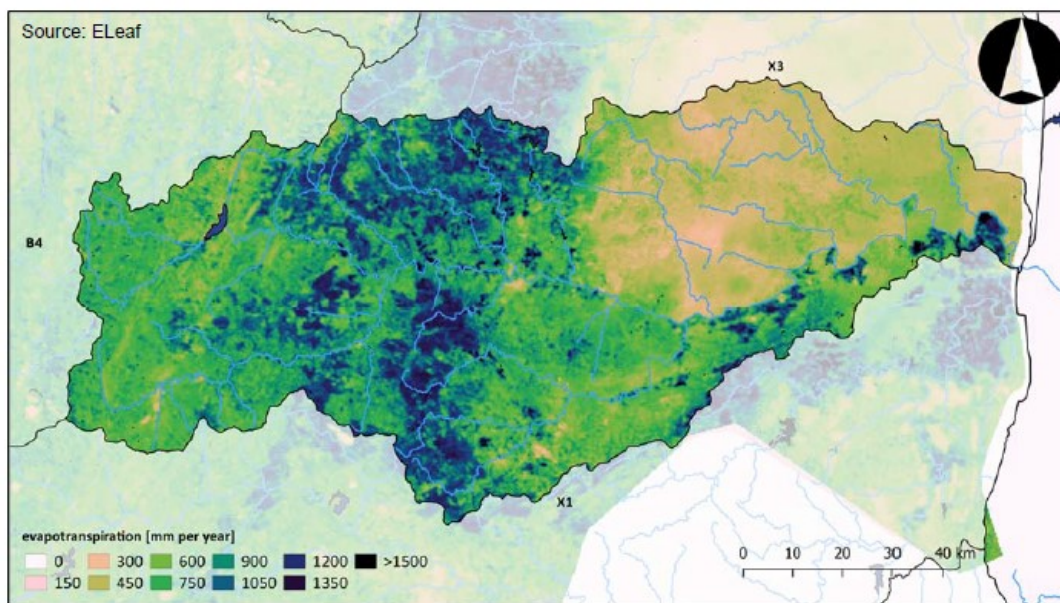
Yearly evapotranspiration in X2 – Crocodile. ref: Van Niekerk, Alvin, Caren Jarmain, and R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018

Remote sensing can be useful and beneficial in solving South Africa's water shortages concerning agricultural potential. While the GIS database for South African water management for agriculture may be well developed, the is little use and implementation of the data available. The complete and wide scope that this data covers will allow agricultural production to better relate to localized, focused regions. This database

also allows for user input, which will improve future algorithmic predictions in all fields. The implementation of more Field Wetness Indicators may also improve analytical and statistical results.

WA Agricultural Services in X2 – Crocodile. ref: Van Niekerk, Alvin, Caren Jarmain, and R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018
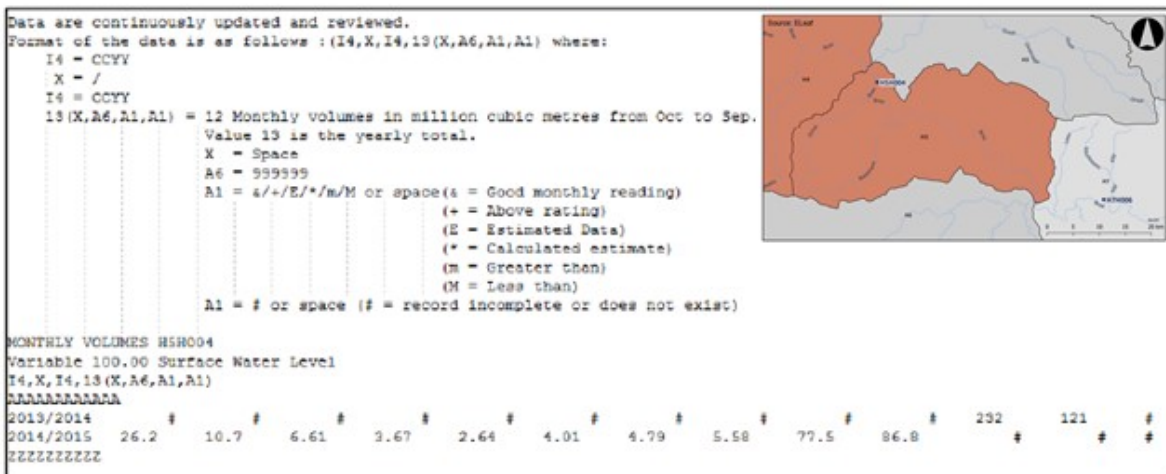
Locations of operating DWA water stations H5H004 and H7H006 and Original monthly river flow data of station H5H004, acquired from DWA. ref: Van Niekerk, Alvin, Caren Jarmain, R. Goudriaan. An Earth Observation Approach Towards Mapping Irrigated Area and Quantifying Water Use by Irrigated Crops in South Africa. Water Research Commission, 2018.

Understanding the weaknesses of the Agriculture Sector in Angola: an overlooked sector

Although agriculture is considered to be the base economical sector of Angola, and it has a high potential to be diversified and exploited to become an economical source for the country, it is not being efficiently utilized and exploited due the lack of data gathering around the country for Agricultural Purposes. To understand a little bit more of this sector in the country the mapping done through remote sensing in the country has been gathered to illustrate the few data base available now and to analyse where can remote sensing help in improving the agriculture in the country. The only places that seem to have a little bit of agricultural data base are Huambo, Bié, Malanje, Huíla and Benguela.
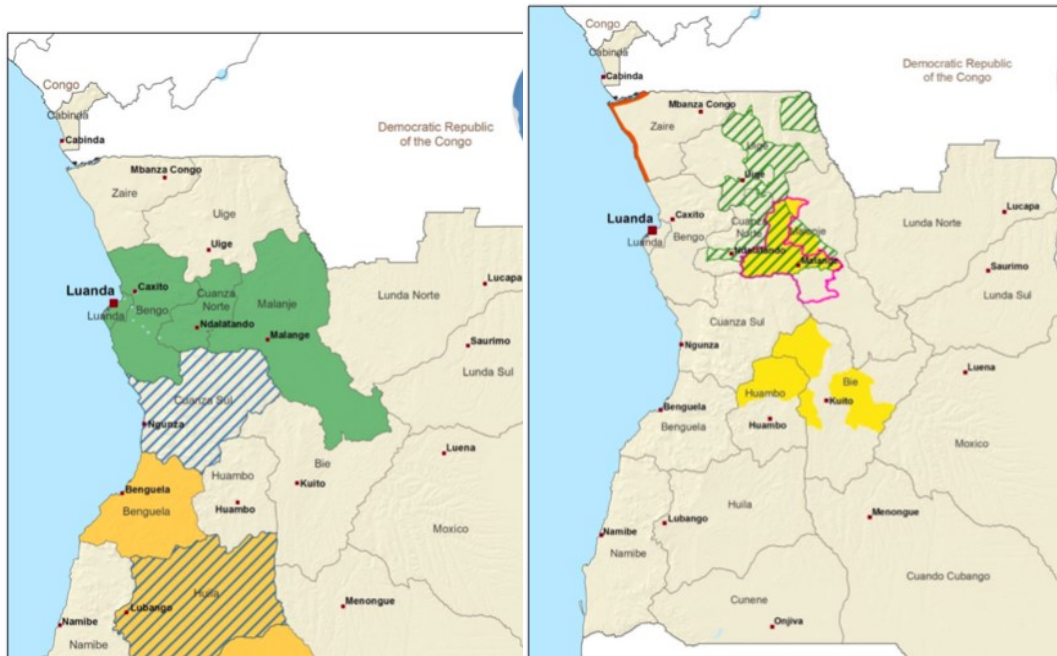
Shows the 2018 Strategy to Recover areas of agricultural value. Through this map one can see that the maize Market Oriented areas are around Huambo, Bié and Malanje which also happen to be the only areas that actually have had data gathered through Remote Sensing
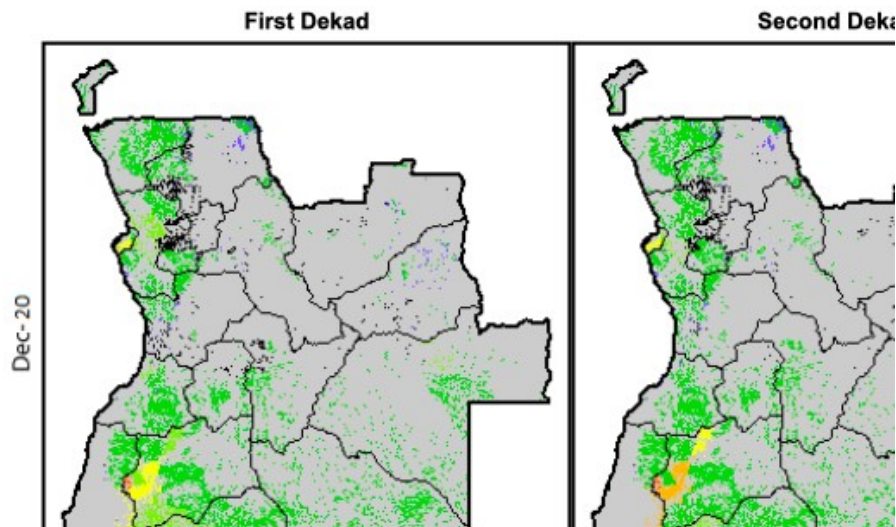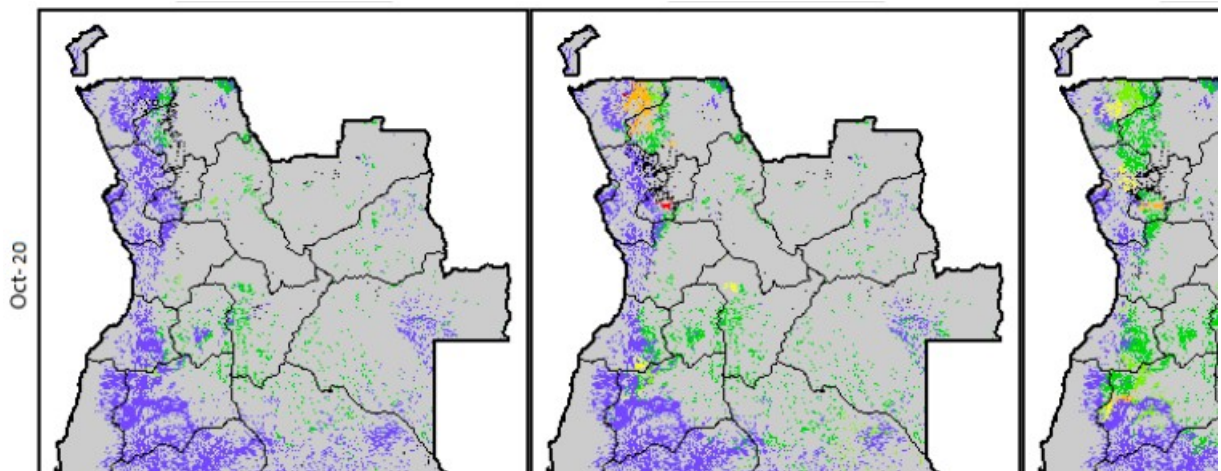
Seasonal crop indicator

According to a study made between 2009 and 2010, about 99% of the cultivated areas are occupied or farmed by local families. The Three biggest problems associated with Agriculture in Angola are not actually resources, is in the lack of registered rural areas as there is no actual data base of the rural areas available in the country, the lack of funding for agricultural practices and the still existence of mines left by UNITA in most of the farm areas back in 1922. It is estimated that in a Angola with about +30 Million People, there were place about 15 Million Mines in areas for cultivation.

Resources Available: Coffee, Cotton, Sisal and Sugar, Ebony, Eucalyptus and Pine Trees, and many more. Currently the production of wood is the biggest in the country but only used for national use.
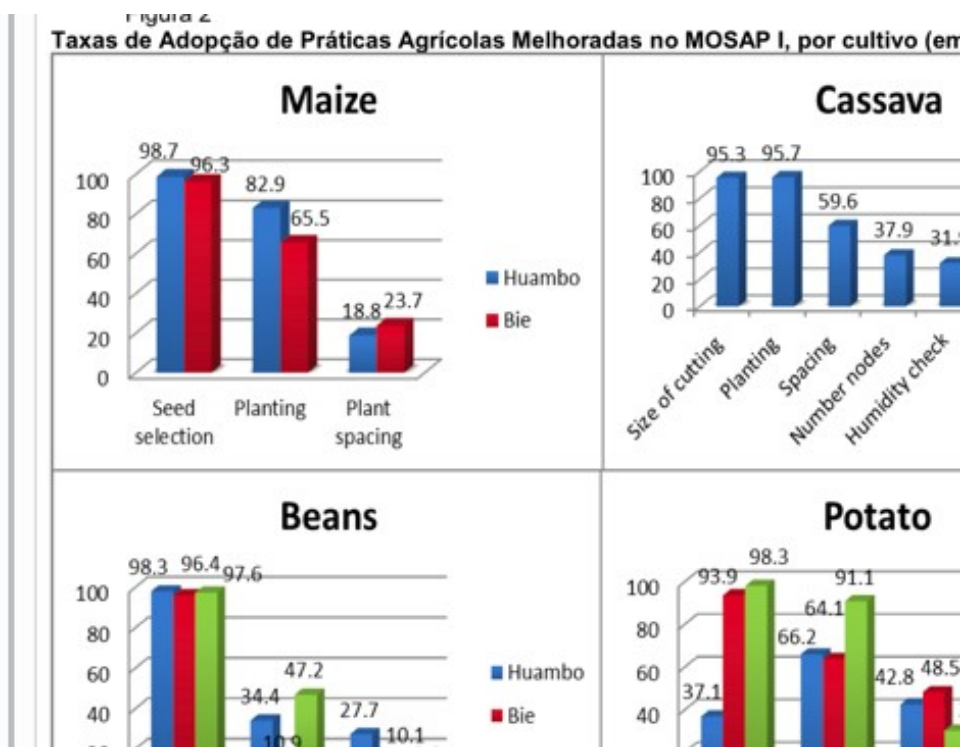
Graphs about the growth of crops due to better farming practices
according to the areas of agricultural practice

The first talks about using GIS for Agriculture in Angola have only started recently and in this work an overview will be done on the country and how GIS and Remote censoring can help to organize and analyse the different areas suitable for cultivation in the country, areas prone to still having mines, grouping the areas with their most prominent resources, and therefore create efficient and structured way to control, preserve and possibly take advantage of the Agricultural Sector in the Country.

Capacidade de Avaliação dos Projectos

Critérios/Projectos	MOSAP I	AFAP	SAMAP
Dadas da eficácia	Novembro 2009	Agosto 2015	Agosto 2017
Nível de execução do empréstimo do FIDA (30 de novembro de 2017)	100% (Completo)	20%	0%
Critérios			
Relevância	Sim	Sim	Sim
Eficácia	Sim	Parcialmente**	Não
Eficiência	Sim	Parcialmente**	Não
Sustentabilidade	Sim	Não	Não
Impacto na Pobreza Rural	Sim	Não	Não
Inovação, replicação e ampliação		Não	Não
Recursos Naturais e Ambiente	Sim	Não	Não
Adaptação as Mudanças Climáticas	Sim	Não	Não
Igualdade de Género	Sim	Parcialmente**	Não

Data base for investments and loans regarding natural resources and agricultural practices
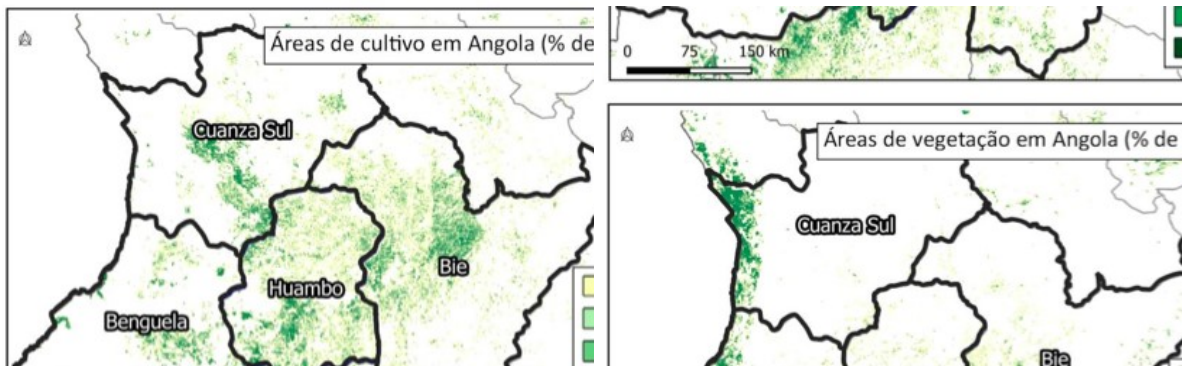
Maps of the Cultivated areas (Top) and Vegetation (Bottom) of Angola.
Font: EC-JRC ASAP Warning Explorer

The use of Remote Sensing for Agriculture in Angola is still along a way to go and a lot of data to be gathered in order to truly understand the agricultural sector of the country. Remote Sensing would help not only the farmers and people in the rural areas but also the investors to evaluate areas of higher and lower risk of future investment for farming.
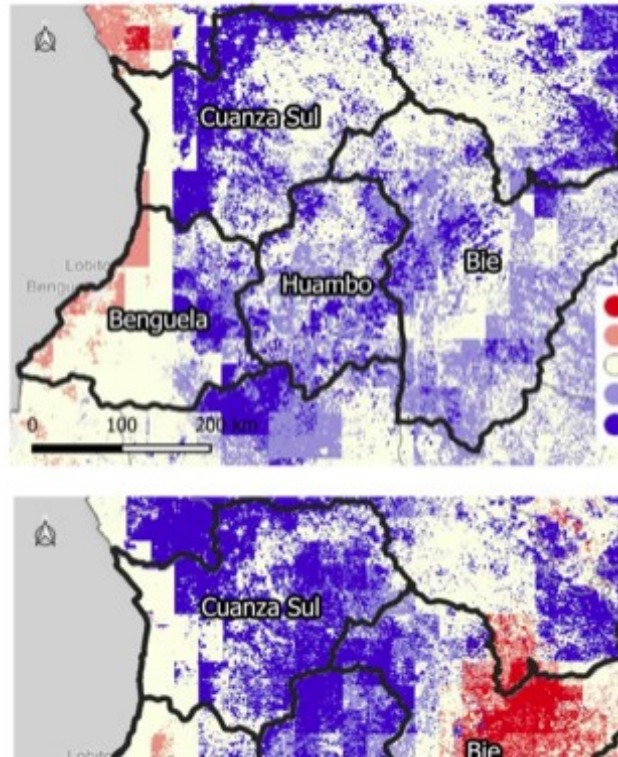
Spatial Distribution of anomalies in the Indices of Satisfaction of the Water for cultivation.
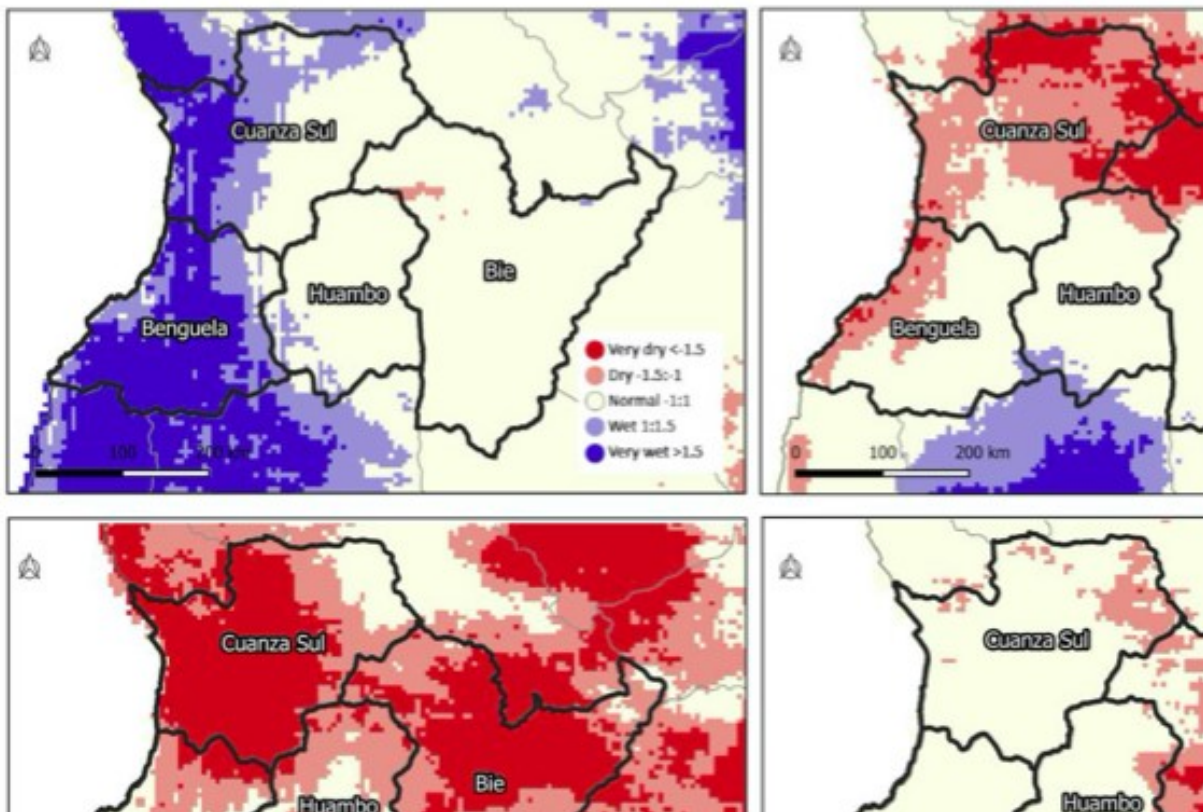
Spatial Distribution of Pattern of Precipitation during 3 months. October-Dezember 2019 (top left), January-March 2020 (top right), October-Dezember 2018 (bottom left), January-March 2018 (bottom right)

35

Currently since the use of GIS is still somewhat recent and basic, one notices that the data gathered so far focuses mainly on crop and grass lands only, more in-depth studies are missing and that's where GIS Remote Sensing can help to gather and analyse future information in a more structured way as many of the last agricultural surveys are old and hand made. Remote Censoring can be useful to predict investments, areas could be organized according to their prominent resource in order to facilitate the extraction of resources, areas with natural water resources and most important areas with different degrees of danger due to the mines placed during the war.
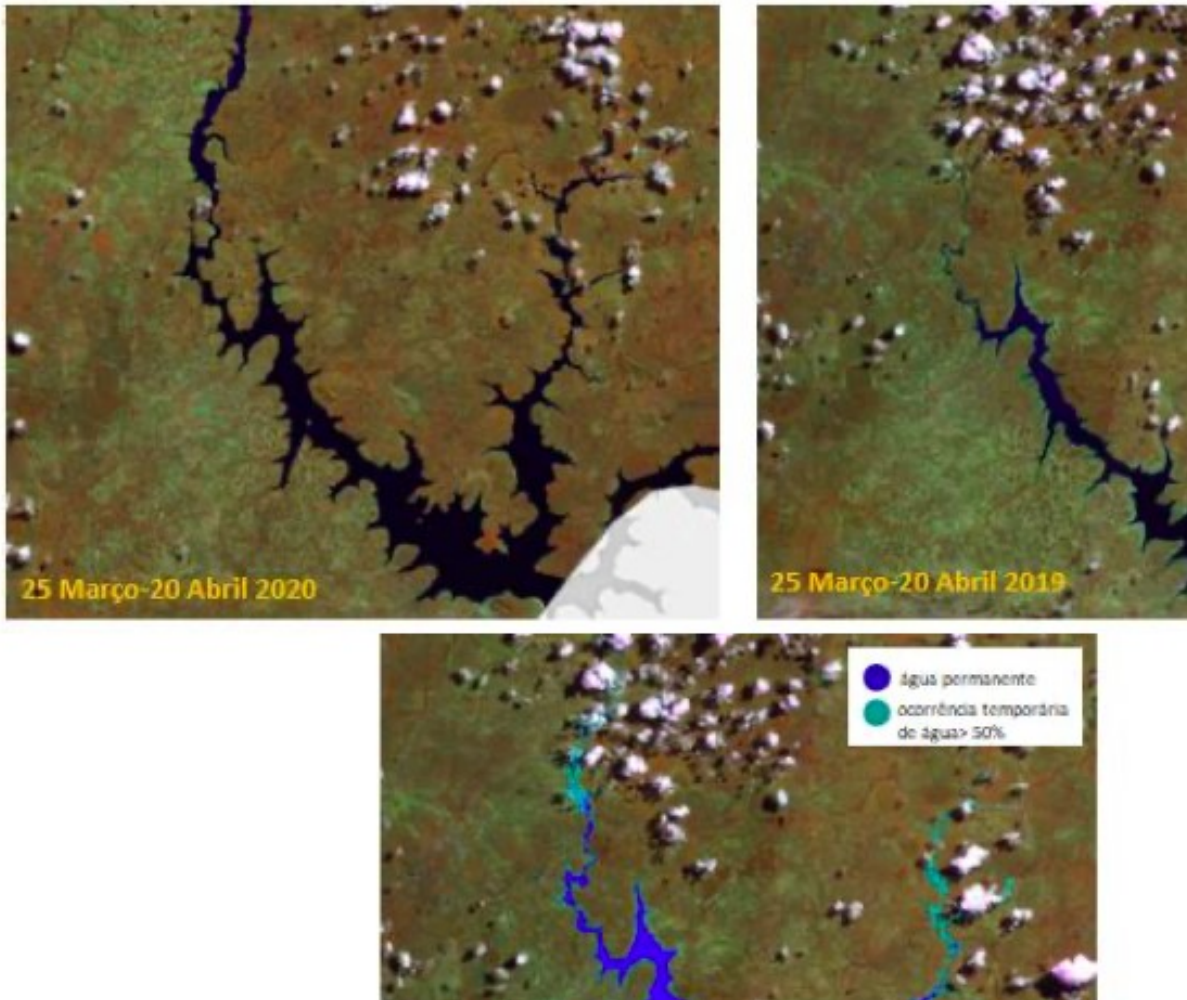
Gove Dam in Huambo 2020 (top left), in 2019 (top right) and the layer of Water ASAP for reference (bottom) Systematization of the Resources, Weaknesses, Treats and Opportunities for use of Remote Sensing for Agriculture in Angola

Since Agriculture is mostly used for national use (whilst in Brazil it is used for both national and international uses), this sector is unfortunately overlooked. Agriculture at the end like everything else depends and its highly influenced by education levels in the area and finances, therefore, Remote Sensing must be used not only to directly impact this sector, but also to study the different educational levels in the country as well as economic wealth.

Resources

Raw Material
- Sugar
- Coffee
- Cotton
- Sisal

Trees
- Ebony
- Pine Trees
- Eucalyptus

Treats
- Existence of mines in cultivated land
- Lack of registered rural areas

Weaknesses
- Lack of registered rural areas
- Existence of mines in cultivated land
- Lack of funding for agricultural practices

Benefits of Remote Censoring
- Danger areas prone to still having mines from the war
- Analyzing areas by their most prominent resources
- Useful to predict areas suitable for investments
- Areas with natural water resources
- Analyze the different areas suitable for cultivation in the country
- Study of the different types of soils

Angola agriculture

GIS for historical heritage and restoration [17]

Work project

1. **Digital photogrammetry –** Oddly enough, digital photogrammetry is still in the first place. Although its result is less accurate, it is more extensive. This method of obtaining information is not the main one, but it is hardly the most important. After all, it is he who "patches" holes in the exact data of laser scanning. And the whole generality of the collected data depends on the absence of these very holes.

2. **Laser scanning –** It starts with a precise laser scan performed directly in the project coordinate system with a less accurate scan performed using the scan-to-scan field stitching method. This allows you to get the job done quickly and accurately.

3. **360-degree photography –** It is an additional tool to get the necessary details and to check and possibly correct errors

4. **Data combination –** The most important thing after all that has been said before is to put everything together well. Combine everything into a coordinate system, supplement with accompanying material, prepare the object so that other participants in the work with this data would be comfortable and comfortable performing their part of the tasks.

A case study: Assumption Cathedral of the Tula Kremlin (1766)

Tula, Russia (localization: 54°11'42" N, 37°37'11" E)

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[17] Excellent preliminary report written by Mayya Sargsyan (Armenia).
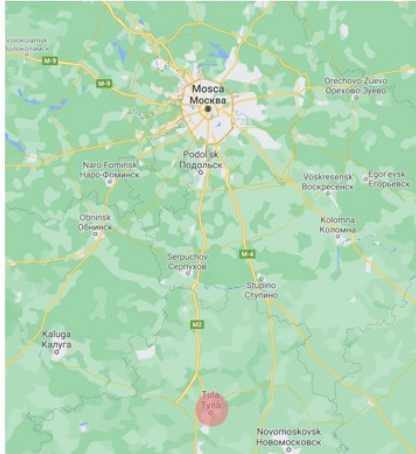
The Assumption Cathedral was opened in 1764, its construction lasted two years. The cathedral itself is unique in that outwardly it does not at all look like typical temples of that time. Its interior contrasts with the exterior and was made in the Russian Baroque style. For more than 200 years of its existence, the cathedral has suffered a lot: they were going to open an atheist museum, then there was a warehouse. Some of the frescoes were irretrievably lost, something worn out over time, something from physical impact.

Restoration of the Cathedral thanks to the use of GIS

The iconostasis has survived to our time in a relatively tolerable condition, but not without losses. The carved decor of the iconostasis has survived only by 30%.

Traditional methods of restoring wood carving involve a large number of manual labour of masters. And such carving "in front of the eye" is still not ideal for preserving the historical heritage. Therefore, it was decided to attract modern technologies, in particular 3D scanning. This decision was made for three reasons:

❑   3D scanning allows you to create identical ornaments;
❑   this technology allows you to restore the lost part of the thread;
❑   the restoration process is accelerating.

In addition, a digital copy of carvings and ornaments is easier to store than the original carvings. And it is always possible to restore those parts that may suffer in the future for any reason.

In our case, the task was as follows: to conduct a 3D scan of iconostasis ornaments. Then the customer on his side with the help of CNC machines carved copies of the products according to our 3D models, and at the next stage the masters manually modified them.

3D scanning in action

Details of ornaments

Then it was time to stick labels, gradually the architectural artefacts were covered with "dish". Tags could not be done without tags in this case, as the threads were very embossed and had deep interiors. Labels allow you to "stitch" scans into a single 3D model.

First of all, the 3D scanner was calibrated according to the size of the objects for scanning, in progress.
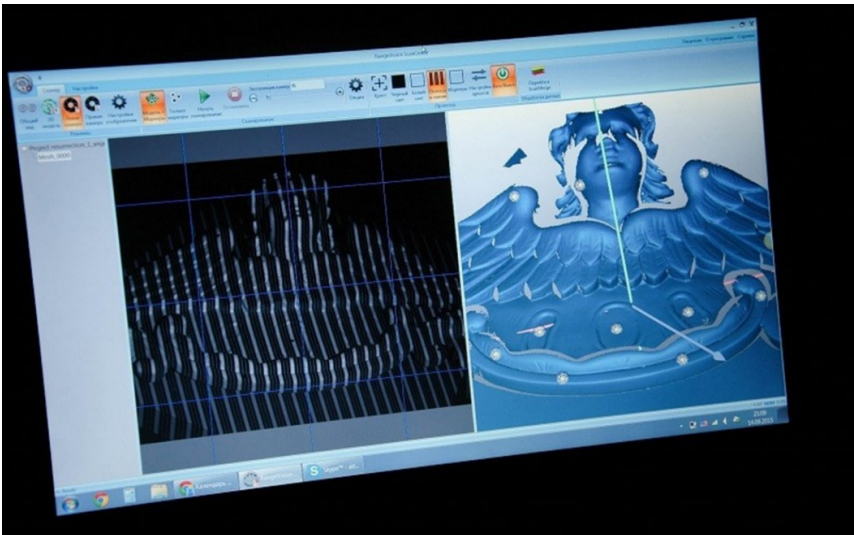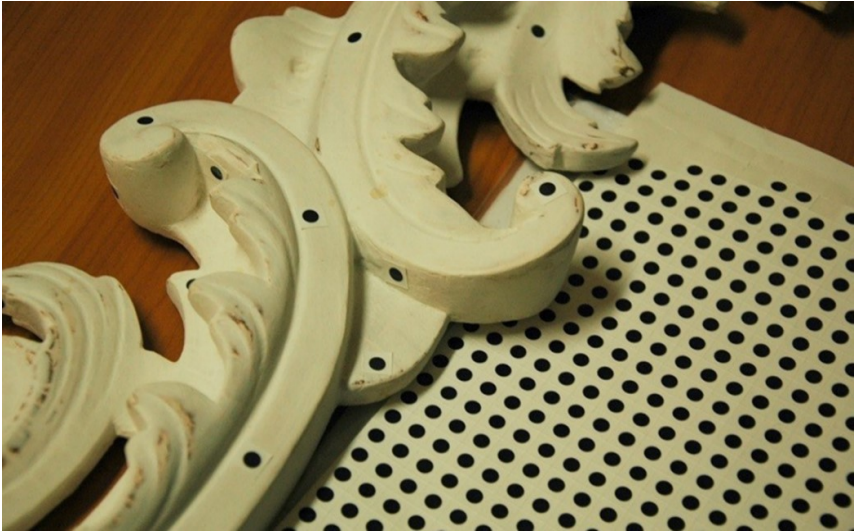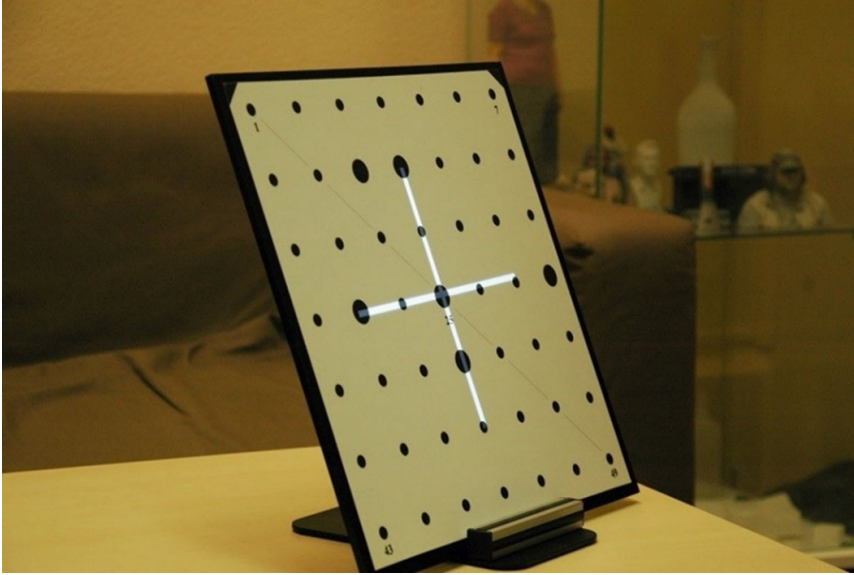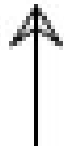
Having 3D models of threads and other parts of the iconostasis in their hands, customers used a CNC machine to sharpen the necessary work-pieces from wood. Then the masters manually modified them, giving the necessary detail, roundness and softness to the patterns. In the photo below you can see an approximate step-by-step production of iconostasis carving.

Therefore, at the end of this work, preservation of cultural and historical heritage is a serious and often difficult task. It requires a lot of investment of resources, both human and financial. In addition, this case can become very time-consuming, which again leads to an increase in financial investment.

The involvement of 3D scanning specialists leads to obvious savings in all three components:

- time;
- money;
- works of masters.

TGIS for Historical Heritage from research to application [18]

A case study Old Summer Palace

The Old Summer Palace, or Yuan Ming Yuan, is an imperial complex of palaces and gardens located in Beijing, China. The garden was known as "Garden of Garden", a representative work of Chinese imperial garden and palace design for its extensive collection of landscape, architecture, art and historical treasures.

History and background

Garden of gardens 3.5 km^2

1707 construction

1725 expansion

1747 European palaces

1860 destruction

1870s failed reconstruction

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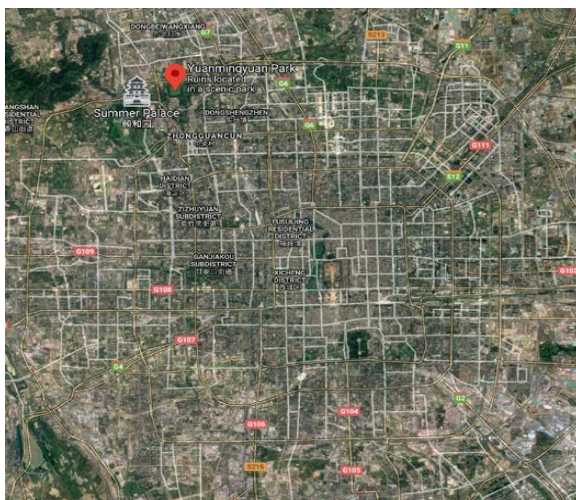
[18] Excellent preliminary report written by Lai Yiqi, Song Ruiming Zhao, Guijia (China).
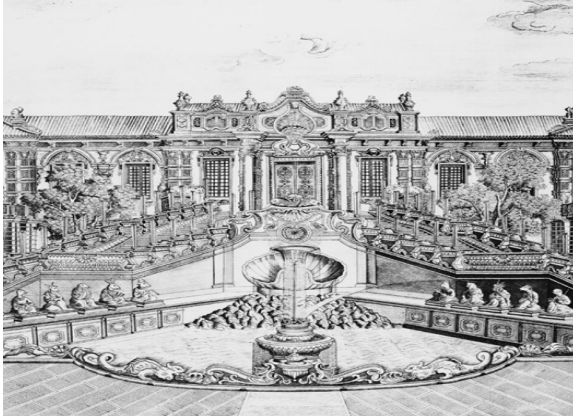
Its initial construction started in 1707 during the rule of Kangxi Emperor of the Qing Dynasty, the last imperial dynasty in the history of China. The Old Summer Palace was the main residence for handling state affairs since Qianlong Emperor, who also ordered the 2nd expansion of the garden and the European-styled palaces. The destruction of the Old Summer Palace during the Second Opium War is an important chapter in the history of China. Historians never reached an agreement on debate of whether to reconstruct the palaces and garden, to rebuild the glory of its heyday or to leave it as ruins to remind people of the past.

Input   Output
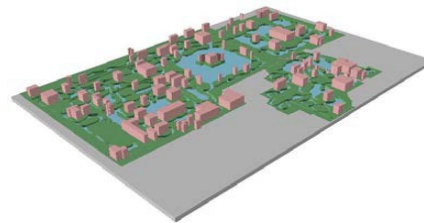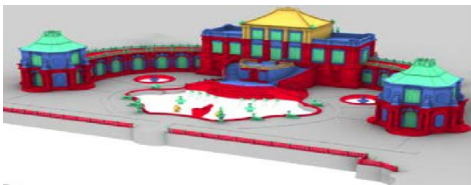
RESEARCH   DATABASE TGIS   APPLICATION
Documentation   Request & Respond   Communication
Categorizing / Modelling   User

The development of technology in geoscience allows the digital and detailed reconstruction of the Old Summer Palace for the uses of tourism. From the research stage, detailed model can be generated with all remaining artifact on site documentation and categorization as an input source of data to form the local tourist GIS system for the historical heritage site.

The TGIS server would provide onsite access through visual goggles, display tablet or other mobile devices. The output communication platform would utilize different technology to enhance user experiences, which requires further development of apps and interface. The virtual tour plays an important role in propagandizing, protecting and reproducing scenes and decision-making support for any important heritage site.

TGIS

TGIS system aimed to support the tourism and uses the information science to collect update, manage, display, query, analyse travel data. cartographic output travel data. The goal is to provide timely, accurate and convenient services to meet the different needs of various users.
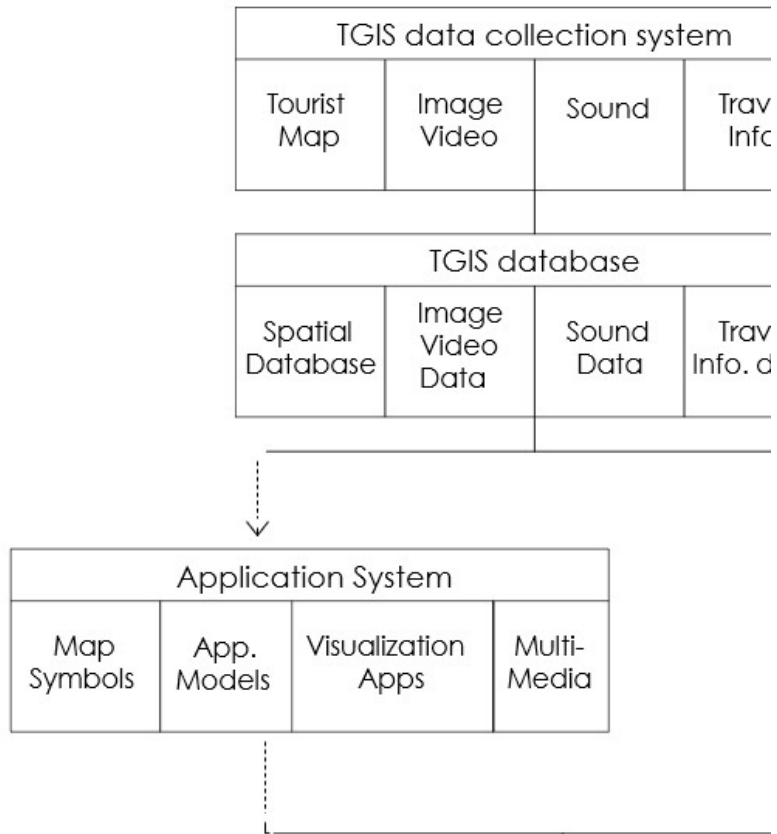
Needs for TGIS

The application of virtual tourism has a broad prospect, that not only fulfill the many different needs but also bring great economic and social benefits:

For tourists, the virtual tourism system can translate the reality into multidimensional experience which provide giving people an immersive sense both past and presents.

For developers and planners, the system can display future design and planning before actual development. It is a great way to obtain feedback and achieve further improvements and perfection that not only reduce the risks of tourism development, but also achieve maximum economic value.

For businesses, virtual tourism can help innovate the marketing model for tourism information and improve the quality of tourism information services. In a competitive tourism market, virtual tourism can help businesses attract more customers and improve the quality of the services. Travel guides and environmental commentaries would be a great way to boost income return.

For the government, virtual tourism allows the implementation of macro-control of the tourism industry and the possibility of more sustainable development when dealing with historical heritage site.

TGIS technology

There are 4 main research direction that contribute to the development of TGIS systems.

Panorama:　　Image based;

　　　　　　　Java and WebGIS to achieve interaction.

Use panoramic technology to generate panoramic images, establish panoramic model of tourist attractions, and then use Java and WebGIS to realize dynamic interaction and roaming of tourist attractions. The scenery described by panoramic images is fixed and the roaming process is repeated and monotonous.

VRML/X3D: Modelling language based on HTM multi-stage and multi-texture rendering on local server.
Access of VRML is based on the Client/Server model. The server provides VRML files, which are 3D scenes described in text information and transmitted by the Internet. Then the 3D scenes are generated by the VRML browser on the client. This working mechanism avoids directly transfer of graphics files on the network, and hand over complex tasks to the local machine, thereby reducing the burden on the internet connection.

Scripting: JAVA 3D, Direct X, OpenGL, XML etc. Language and software bases for 3D visulization
Scripting is the most frequently method with better effect which requires high programming skills.
Java3D is based on low-level APIs such as OpenGL or DirectX. It is an extension of the Java language in the field of three-dimensional graphics. With its rich library, Java3d takes full advantage of the powerful functions of the Java language for generating complex three-dimensional applications and ensure strong scalability.

Web3D: Developed software support argumentative reality
Web3D refers software that are mainly used in the display of products and scenes. Using the API of these software, virtual scenes can be developed, and simple animation effects can be realized. There are many such products, such as Viewpoint, 3DML, Vecta3D, KOVI3D and so on.
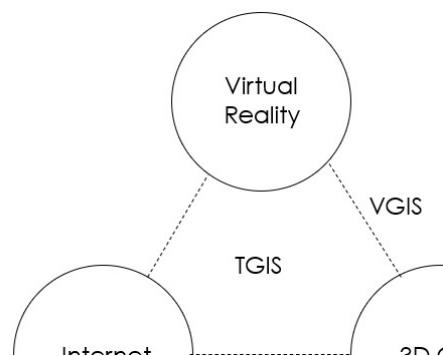
Visual realization

Although the current network and computer technology have been greatly developed, the contradiction between the fidelity of the virtual landscape and the network transmission speed and the limitation of computer hardware is still a setback in the user experience of the tour. Therefore, different levels of models is required to boost the smooth experience for tourist but also release the pressure internet server.

Park level of GIS model defines simple relationships of monophonic buildings, trees and pathways while building level model provides more in-depth texture and historical information.

Level of details

❑   Park level;
❑   simple modelling, defining relationships.
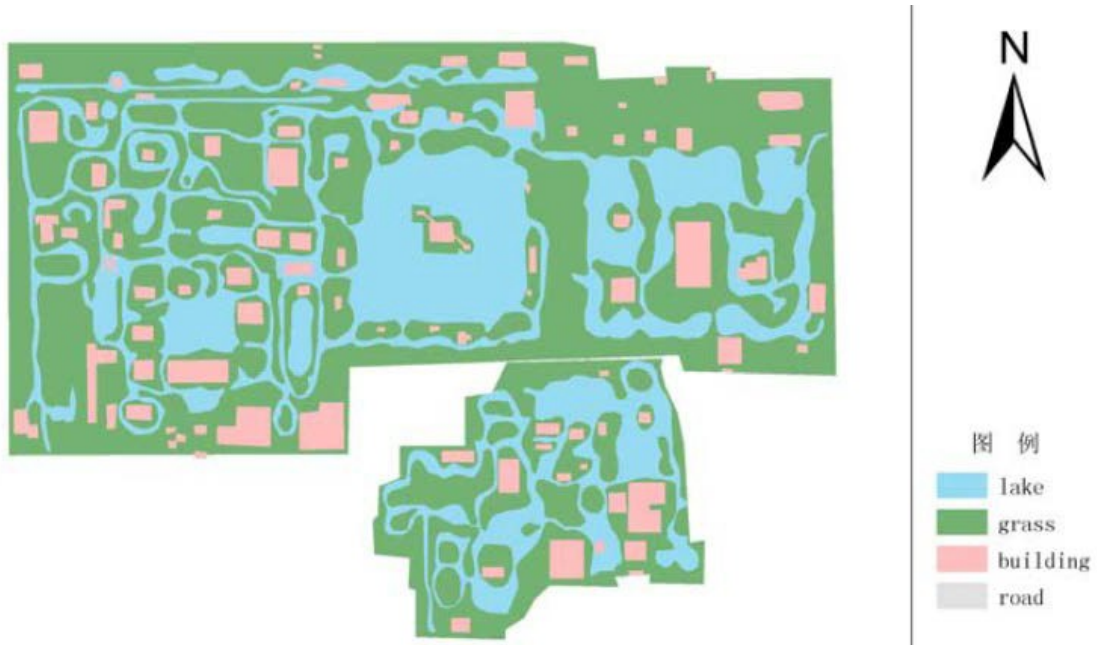
Map of old Summer Palace – Park level reconstruction /Diagram from Jiang, WenYan
https://v.qq.com/x/page/x0861ll2wum.html?start=190

❑ Building level;
❑ detailed models with full textures.

3d Map of Palace / Diagram from Jiang, WenYan

DATA STRUCTURE

INTERACTION SYSTEM
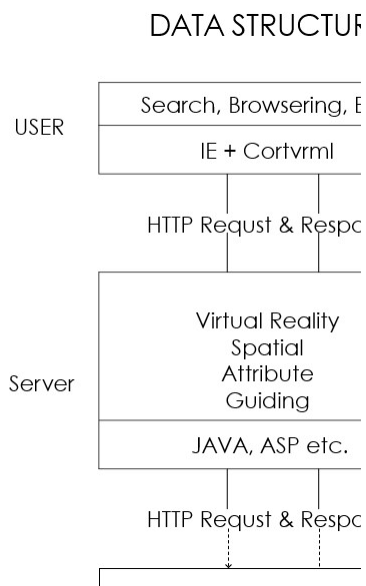
In the system structure, the current virtual travel system generally adopts a three-tier structure: client layer, server layer and database layer. The client layer implements 3D virtual scenes and roaming and information query. The server layer includes network servers and GIS servers. The network servers mainly act as agents and buffers. The GIS server mainly performs data analysis and logical processing. The database layer mainly stores attribute data and Spatial data.
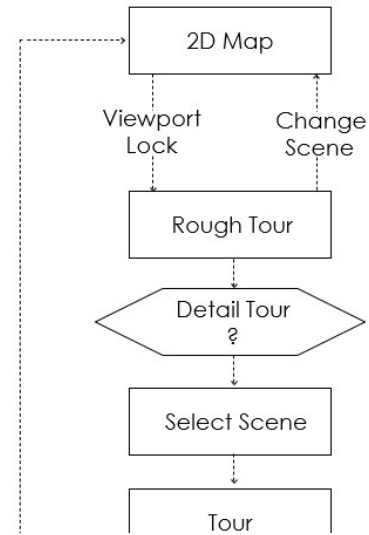
Digital restoration research: Xieqiqu
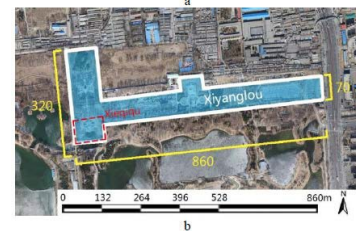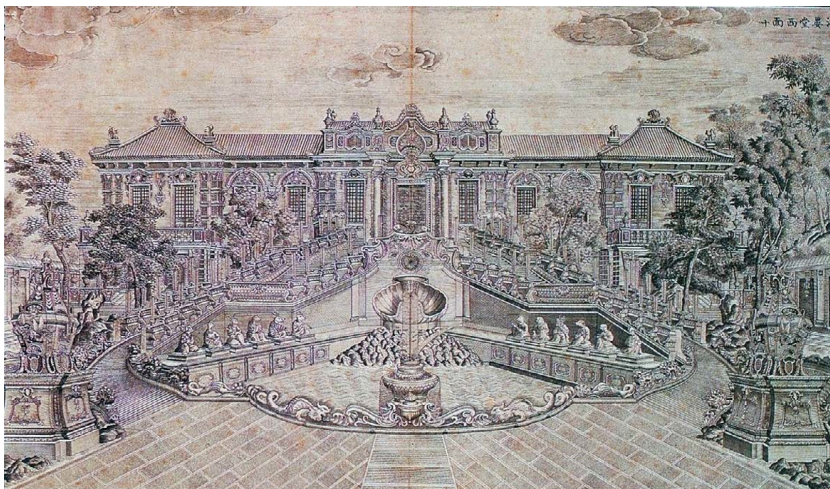
Diagram from Gao, Ming
https://commons.wikimedia.org/wiki/File:Yuanmingyuan_haiyan.jpgFile:Yuanmingyuan_haiyan.jpg

Xiyanglou is located at the north tip of Changchunyuan. Its construction began in 1747 and completed in 1783. The complex consisted of over dozens of Western-style buildings and gardens in a "T" shape layout, stretched 860m on the east-west axis. The west end of the site was 320m in the north-south direction and 70m wide. The site covered an approximately 8 acres of land in total.

It was designed and constructed collaboratively by Jesuit missionaries worked for the Imperial Court, Giuseppe Castiglione and Michel Benoist, and the Chinese craftsmen. The entire scenic region, including buildings, fountains, sculptures, and gardens, were built in Baroque and Rococo style using traditional

48

Chinese construction techniques. With an emphasis to showcase the spectacular western hydraulic system, Xiyanglou was the first large scale introduction of the Western garden and architectural style into the Imperial resort. In 1860, British and French troops plundered and burned Yuanmingyuan. Xiyanglou could not escape from its doomed fate. After a few more disasters over the course of history, the site had been severely damaged and was reduced to the ruin today.

The scenic region of Xieqiqu covers an area of 9956 m^2 in total with 235 m^2 of the land taken up by the buildings. The architectural layout was in the form of a semi-arc. The main building consisted of three levels. The ground level had seven bays, flanked by a semi-circle podium in the front and a three- bay porch at the back. The second floor also had seven bays, while the top floor had three. Curved corridors with nine bays in length extended from both east and west side of the main building; each had a two-story octagon music pavilion attached at the end. Columns in Xieqiqu were made by bluestone in the form of Classical Doric Order. The roofs were covered with glazed tiles. The butterfly staircases at the south provided direct access to the patio on the second floor. At the center of the courtyard, in front of the main building, there was a large multifold fountain and another barbed quatrefoil fountain was located on the north side of the main building.

Techniques deployed during the information acquisition stage

The majority of the remains of Xiyanglou are immovable artefacts. Yuanmingyuan Administration made an attempt in the 1980s to restore and reassemble the fragments. However, due to technical and site limitations, the restoration remained incomplete, at the same time created challenges for future data acquisition and classification. In order to optimize the accuracy and completeness of the digital data, four different techniques were deployed during the information acquisition stage: Aerial Photography, Laser Scanning, Total Station and Manual Recording. The exact measurement, structure and material property of the source object were meticulously reflected on the 3D model, to represent and share the proper heritage information.

The data acquisition and classification of Xieqiqu counted a total of 800 stone components on site. 53 pieces of stone elements with distinctive characteristics were identified. Among them, 47 pieces were catalogued in the database with their exact location marked correspondingly on the copperplate etchings and the aerial photographs.

Diagram from Gao, Ming

Set up restoration catalogue & database

The excavation unearthed approximately 300 pieces of the glazed components, from the archaeological site

of Xiyanglou. These fragments were relatively small in size, with different color and dimensions. All the archaeological findings are currently housed in the storage facility of Yuanmingyuan. The initial inventory of the storage identified 80 different styles. Through cross-referencing of the glazed components' surface pattern with the historical photographs, the exact location of 12 pieces of the fragment had been identified. The diversity of style and colour of the decorative components, as well as location restoration of the pieces are shown in the image below.
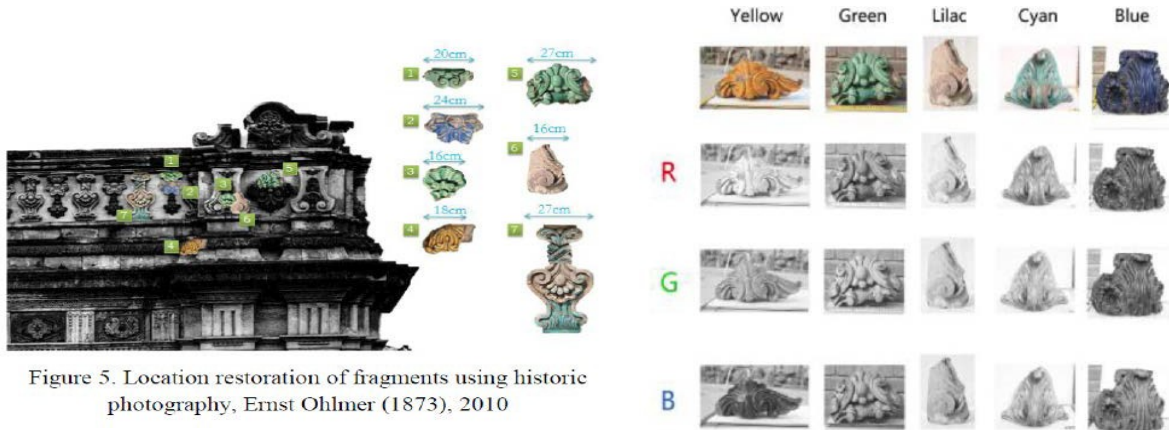
Figure 5. Location restoration of fragments using historic photography, Ernst Ohlmer (1873), 2010

Diagram from Gao, Ming: location restoration of fragments using historic photography (Ernst Ohlmer, 1873)

Evaluation of historical material

There aren't any photo records of Xiyanglou prior to its destruction in 1860. The earliest surviving image of the site was a set of 20 frame photos taken by the German photographer Ernst Ohlmer in 1873. Between 1876 and 1877, Thomas Child and A. Théophile Pir also took some pictures of Xiyanglou. The end of 19th century and the beginning of 20th century saw an increase in the photographic record of the site. Photos from this period featured in relatively liberal shooting angle, recorded the ruins of Xiyanglou at various perspectives at different times of the year. The research team has collected 92 historic photographs up to date.

During the construction of Xiyanglou, Western drawing techniques were already known to China. Between 1781 and 1786, a series of 20 copperplate etchings were made under the name of Yuanmingyu Xiyanglou Tongbanhua (Western Buildings of the Old Summer Palace). These drawings provide the closest visual reference to the glorious heyday of the site.

The following diagram is the overall site plan of Xieqiqu drafted by the Lei Family. This drawing is the most annotated blueprint known to date, carried more than 120 dimensions information when most of the blueprints only contained up to 20 annotations. Many measurements of the northern staircase on the blueprint are different from the measurements collected on site. The foundation of the staircase is relatively intact, without evident of dislocation. Further analysis of the plan reveals traces of modification; indicate that it was a working draft during the design process with a level of uncertainty. Therefore, all researches related to the Yangshi Lei drawing have to be cross-referenced with the on-site condition.
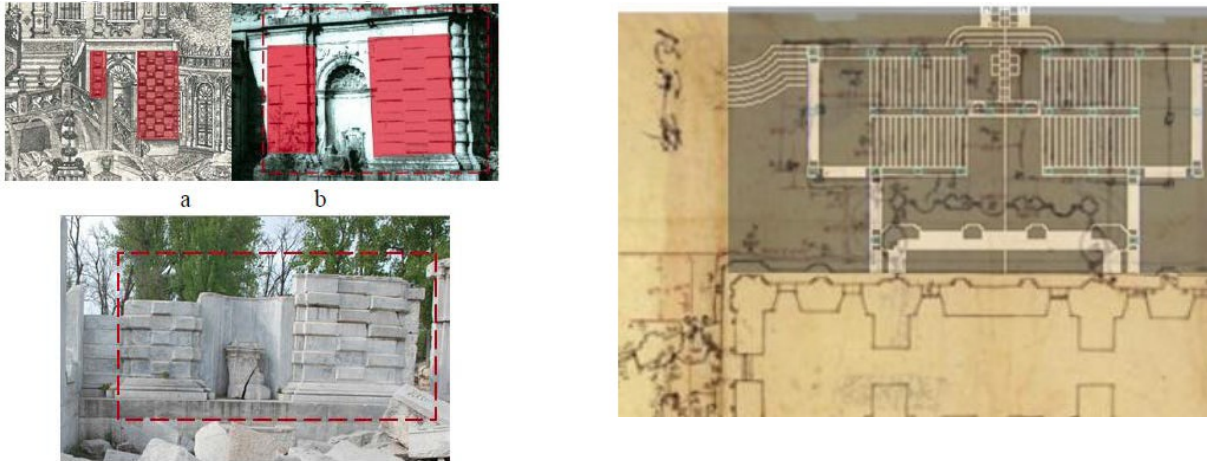
Diagram from Gao, Ming: Xieqiqu, flor plan, Yangshi Lei drawing 985 (1744-1751)
National Library of China, Yangshi Lei Archive)

Construction of the Digital Model

Detailed model for tourist system. The digital reconstruction model is one of the main achievements in this restoration project. Experimenting and developing the practical applications of the model is the main focus of the future studies.

Two digital modelling methodologies were deployed to ensure the accurate construction of the digital model, namely CAD based modelling and Point Cloud based modelling. The former method involving produced a detailed CAD drawing using information from both site recording and historical archival research then imported the drawing into 3ds MAX to produce the digital model. The accuracy of the digital model was governed by snap to the points and line segments from the CAD reference. The latter method applies to on-site components that were relatively intact. Point cloud data of the components were collected by the technicians to generate the digital model. Topology technology was used to convert the Dense Cloud high-resolution polygon mesh to

a low polygon mesh, in order to optimize the model's performance in the virtual environment while preserved as much detail as possible.

Level of Accuracy	Source(s) of Reference	Description
A (red)	Archaeologic Site	Digital model built based on the actual components from at the Archaeological site. Information regarding building material, dimension, style, colour, decorative pattern and relative position are accurate and complete.
B (blue)	Historic Photograph	Digital model built based on Information extracted from historical photographs, including building material, dimension, style, colour, decorative pattern and relative position.
C (green)	Copperplate Etchings, Yangshi Lei drawing, Archival Documents	Digital model built based on information extracted from copperplate etchings, Yangshi Lei drawing, and archival documents, Including building material, dimension, style, color, decorative pattern and relative position.
D (yellow)	Traditional Chinese and Western Building Convention	Digital model built based on style and dimensions derived from Chinese Qing Dynasty Construction Standard and Baroque architectural treatises.
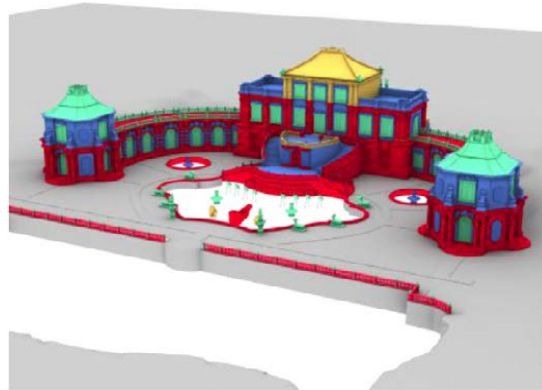
Diagram from Gao, Ming

Application on tourism

On-site digital reconstruction of Old Summer Palace using augmented reality technology. Augmented reality (AR) is a technology that combines virtual objects with real environments to provide information expansion and enhancement for the real scene environment. It can effectively expand the high-level media interaction methods of human perception and expression.

As mentioned before, when the digital modeling is completed, a medium to present them to tourists is needed. AR technology is a very good solution. It can help to reach the On-site digital reconstruction. When AR displays the actual scene and the rebuild model in front of the visitors, they will have a real sense of the architecture and the involved arts.

AR system application

Basic structure
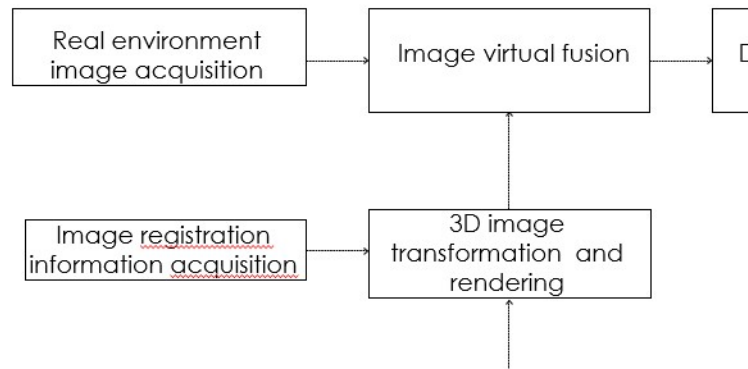
The basic structure of the augmented reality system is shown in this diagram. The system first needs to obtain the real environment image, and then needs to obtain the registration information of the virtual object, that is, the position and posture data required by the virtual object to be accurately added to the real scene. The computer performs coordinate transformation and rendering on the virtual objects according to the obtained registration information, and then superimposes them with the real scene image to realize the fusion of virtual and real. Finally, the enhanced image information combining virtual and real is provided to the user through the display device.

The key technology of augmented reality system

Registration positioning and display are the two most critical technologies in the augmented reality system. Currently, the registration methods used internationally mainly include registration positioning based on tracking devices, registration positioning based on computer vision, and hybrid registration positioning based on vision and tracking devices, etc. Research on registration technology based on computer vision is currently in the leading position in the field of augmented reality, including tracking registration with and without markers. The tracking and registration algorithm without marker points is more complicated and is still in the research stage. Although some progress has been made, systems used outdoors have not yet reached practical levels. Although the registration algorithm based on landmarks is quite rich and complete, landmarks of various shapes or different colors must be added to the scene, which is not allowed in most applications involving cultural heritage protection.

The synthesized image after the fusion of virtual and real needs to be provided to users through display devices, including handheld personal data assistants (PDA), head-mounted displays (HMD) and other different forms. HMD can provide users with enhanced images with a sense of immersion. It has two types: video see-through and optical see-through. The goal of R&D is to provide users with display devices that have the best virtual and real fusion effect, but are also light and smart. It involves the design of new visual optical systems and the research and development of new display devices. The new generation of micro displays in the future will be widely used in head-mounted displays [19].

Fixed-position view AR system

The fixed-point observation augmented reality system used for 3D digital field reconstruction of Old Summer

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[19] [Yongtian Wang, Yue Liu, Xiaoming Hu. Research on Key Technology and Application of Outdoor Augmented Reality System[J]. Journal of System Simulation，2003，3: 329-333.
Ya Zhou, Dayuan Yan. Augmented reality system display exploration[J]. Computer Engineering and Applications, 2003,15:35-38.

Palace is a real-time single-user rotating lens barrel type. This system has three working modes: "real", "virtual", and "enhanced", which respectively display the real scene environment, the completely virtual visual effect, and the augmented reality effect of the fusion of virtual and real. This machine can process images at any of these three stage. For example, at dusk, the building on the reality is yellowish, the machine can process the model, so that the model also presents the same color, to make them better match.

Photoelectric stereo imaging system
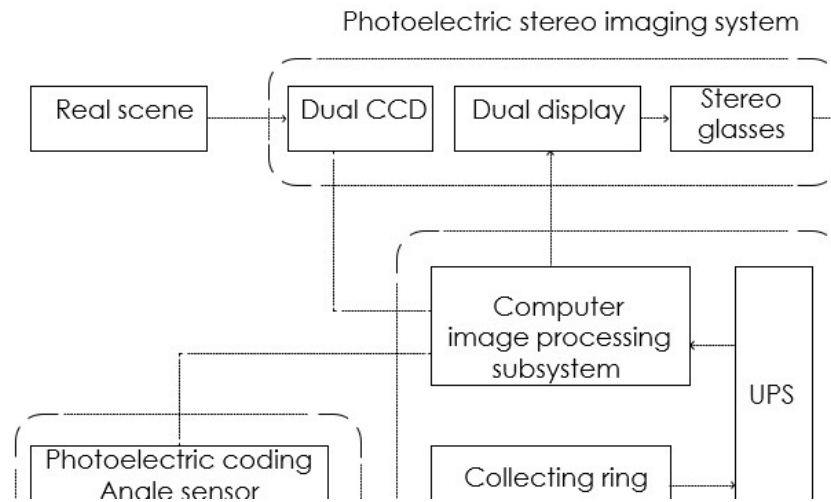
The fixed-point observation augmented reality system used for the 3D digital field reconstruction of Old Summer Palace is a real-time single-user rotating lens barrel type. It is mainly composed of stereo augmented reality photoelectric imaging subsystem, attitude sensing subsystem, image processing subsystem and synchronous rotating platform subsystem. The system structure is shown in diagram3.2, which is the appearance photo of the system. Among them, the photoelectric stereo imaging subsystem is composed of a dual-channel CCD camera, a dual-channel display screen and a stereoscopic eyepiece. The function includes the image of the shooting scene# while displaying the enhanced image in a stereoscopic manner. The angle sensing subsystem is composed of a pan-tilt and a photoelectric encoder, which is used to detect the posture data of the lens barrel. The image processing subsystem transforms and renders the computer model of the old scene of Old Summer Palace according to the posture data of the lens barrel, and compares it with the real environment image Overlay# to achieve the integration of virtual and real. The synchronously rotating mechanical platform is the carrier of all equipment, which can make the machine as a whole and the user follow the load at the same time with UPS and collector ring, to achieve the safe power supply of the system and avoid cable entanglement.

The users of this system use the pan/tilt handle to rotate the camera lens barrel within the range of 360° and ±30° horizontally, and observe the real-time reconstruction of the Grand Waterworks, Observing Water Method, Yuanying View, and Haiyan Hall on the ruins in the Old Summer Palace Scenic Area. The original three-dimensional model of the building can be superimposed and fused with the actual external image.

Angle tracking and follow-up control

Angle tracker and Inertial tracker:

❑ light weight, small volume, convenient,

❑ Mti from Xsens 360°.

All-round angle, long-time working, quick response, continuous output

Yaw ϕ

Roll γ

$$\theta = -\arcsin(2q_1 q_3 - q_0 q_2);$$

Diagram 3.2
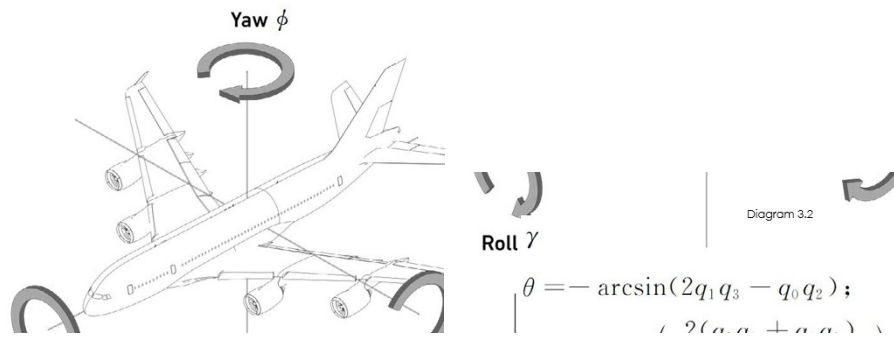
Compared with various trackers such as mechanical type and electromagnetic type, inertial tracker has the advantages of light weight, small size and convenient carrying. Xsens' Mti is a 360° omni-directional attitude and heading measurement device composed of inertial measurement components, which can respond quickly and stably output 3-axis angles for a long time. The micro inertial measurement unit (MIMU) is composed of a micro-mechanical (MEMS) shedding and a micro-mechanical accelerometer. The angular velocity and acceleration of the inertial space along each axis of the carrier coordinate system are measured respectively. The rotational quaternion is represented by Q, $Q=q_0 +q_1 1i+q_2 j+q_3 k$; i, j, k represent the unit vector of the axis of the reference coordinate system, and the attitude angles[1]:pitch angle, roll angle and heading angle calculated by the quaternion method in three cycles, respectively, such as diagram3. 4 shown.

Mti inherits the compensation of temperature, three-position installation error and cross-axis influence, and the nominal precision is 0.1 degrees.

Follow-up rotation control

The real scene camera in the system is installed on a high-precision follow-up turntable, which controls the rotation of the turntable in real time according to the angle measured by Mti.

Start
↓ Mti Data
Exceed the Threshold or not
N ↓
Drive the Rotational Table
↓
Rotate to the Aim
↓
N — Reach the Aim or not
Y ↓
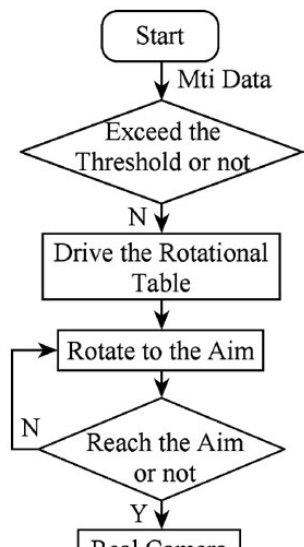
Follow-up rotation control

The real scene camera in the system is installed on the high-precision follow-up turntable, and the rotation of the turntable is controlled in real time according to the angle measured by Mti, that is, the real scene camera is controlled to follow the rotation. Mti can track the three-axis angle of the user's head in real time. Considering that in the fixed-point observation system, the head angle and pitch angle change mainly when the head rotates, so only the heading angle and pitch angle in the three-axis angle information are used as the angle Tracking information participates in processing and control. The first step of the angle control high-precision follow-up turntable is to detect whether the angle information exceeds the rotation threshold. Since the pitch angle may vary between 0-180°, and the pitch angle of the two-dimensional high-precision follow-up turntable is between 0-90°, the rotation of the motor is restricted when the pitch angle exceeds the angle that the motor can rotate. When controlling the two-dimensional turntable to rotate to the target position, it detects the current rotation angle of the turntable in real time, and stops when the rotation reaches the target angle, and waits for the next target position signal.

Restoration application of Yuanmingyuan site
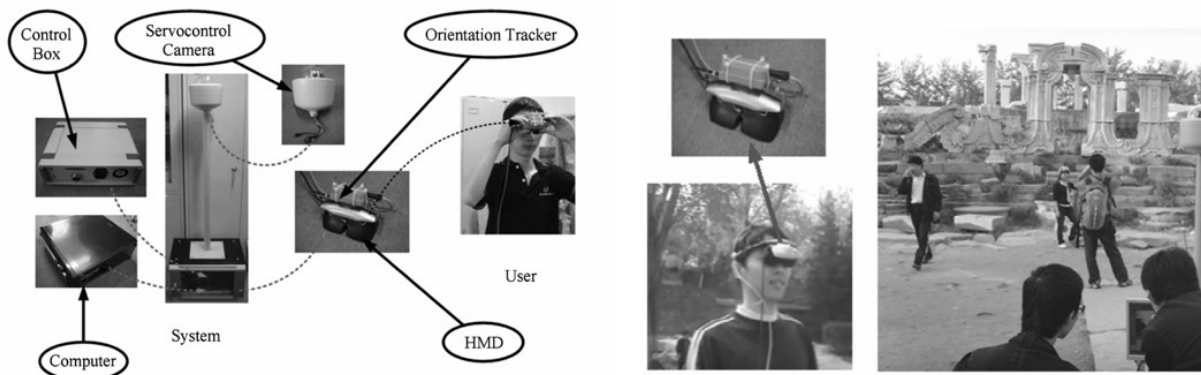
As shown in this diagram, the system hardware equipment is divided into system side and user side. The system side includes computer, control box (built-in high-precision motor driver), follow-up observer (built-in high-precision follow-up turntable, angle measuring device and camera), etc.; the user end includes a helmet-mounted display and an angle tracker.

The separate design of the system side and the user side improves the weight and operational practicability. The system end weighs about 7kg, while the user end only includes a helmet-mounted display weighing 227g and an angle tracker less than 100g. During use, the user holds a portable user-end device and can freely watch the surroundings in place. After the test prototype is set up, field tests have been carried out with the big water method in the Xiyanglou Scenic Area of Yuanmingyuan Ruins Park.

Experimental results

Diagram 3.8 is the preliminary experimental result of augmented reality digital reconstruction of part of the scenes of the Xiyang Tower scenic spot in Old Summer Palace. Among them, (a), (c) and (e) are the real scenes of Grand Waterworks, Throne for Watching the Grand Waterworks and West Water Tower, respectively, and (b), (d) and (f) are the corresponding digital reconstruction effects of virtual and real fusion.

Grand Waterworks ‎ Throne for Watching the Grand Waterworks

Relic view

(a)   (c)

AR
Reconstruction

Appendix: error analysis [20]

Follow-up time delay: Average machine lag: 0s-0.05s Human eye resolution: 0.04s.

In order to analyse the follow-up time delay, the angle values of the head tracker and the follow-up turntable are respectively output when the head rotates severely and when the rotation is normal, and the changes of the two angle values are compared, and the changes are smooth and gentle when the changes are severe. Time delay parameter at time.

Follow-up angle error: Calculation of variance < 0.2°.

In the follwos, figures (a)(b) describe the angle of the bidding, i.e. the angle tracker changes. It changes with the rotating turntable. It can be seen that no matter whether it changes quickly or slowly, the turntable can finally keep up with the angle tracker. In diagram3.9 (a), there is an obvious follow-up lag when rotating 180° within 0.4s in a special case, while the following lag is very small when the normal speed is 180° in (b). Corresponding to (a) (b), Figures (c) (d) describe the lag time curve. The data is collected at each frame of system operation. The curve is intercepted from 50 frames of data at 0.7-1.2s as a reference. The maximum

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[20]

❑ Gao, M., et al. "Digital Restoration Research and Three-Dimensional Model Construction on Xieqiqu." ISPRS Annals of Photogrammetry, Remote Sensing and Spatial Information Sciences, II-5/W3, 2015, pp. 75–81., doi:10.5194/isprsannals-ii-5-w3-75-2015.

❑ Huang, Yetao, et al. "A Servocontrol-Based Augmented Reality Registration Method for Digital Reconstruction of Yuanmingyuan Garden." Journal of Computer Research and Development, vol. 47, no. 6, 2010, pp. 1005–1012.

❑ Jiang, Wenyan. "Research and Realization on the Wandering of Virtual Tourist Landscape- As a Case Study of the Scene of Yuanmingyuan Ruins Park." Institute of Geographical Sciences and Natural Resources Research, CAS, 2008.

❑ Wang, Yongtian, et al. "On-Site Digital Reconstruction of Yuanmingyuan Using Argumented Reality Technology." Science & Technology Review, vol. 24, no. 3, 2006, pp. 36–40.

hysteresis in special cases does not exceed 0.4s. In normal rotation under normal conditions, the lag of the follow-up turntable is between 0-0.05s, and the average lag is lower than the human eye resolution of 25fps (0.04s). Therefore, in normal use, the speed of the angle follow-up control can meet the real-time requirements of the tracking system in outdoor augmented reality.

The error of virtual and real superposition in the servo system mainly comes from the type B error between the angle tracking output angle and the rotation angle of the turntable. The angle tracker is placed on the measuring turntable, and when it rotates to a fixed angle, the actual rotation angle of the following turntable is checked. The error is defined as the deviation σ of the actual angle between the tracker and the turntable. In the experiment, the angle tracker rotates at 10°-360° intervals from 10° to 10° in the horizontal direction; and from 5°-90° to 5° in the pitch direction to measure the actual angular position of the rotating turntable. And draw the error of the horizontal and pitch directions of the follow-up turntable under the control angle, as shown in diagram 3.10.

Calculate the standard deviation of all error values, and get $\sigma_{heading}$ =0.198°, σ_{pitch} =0.187°. The actual measurement standard errors of horizontal and pitch are both below 0.2°, indicating that the follow-up turntable has high tracking accuracy.

58
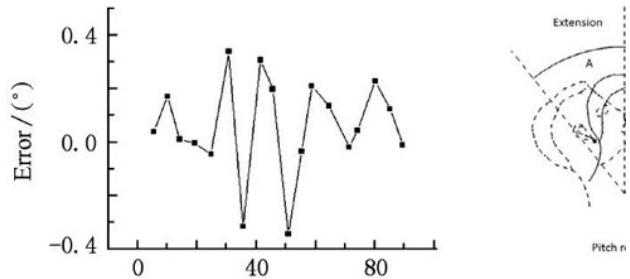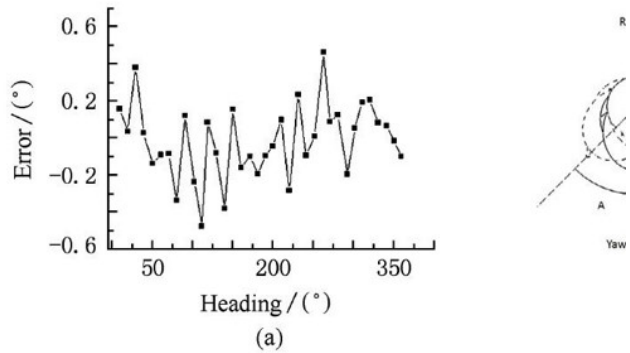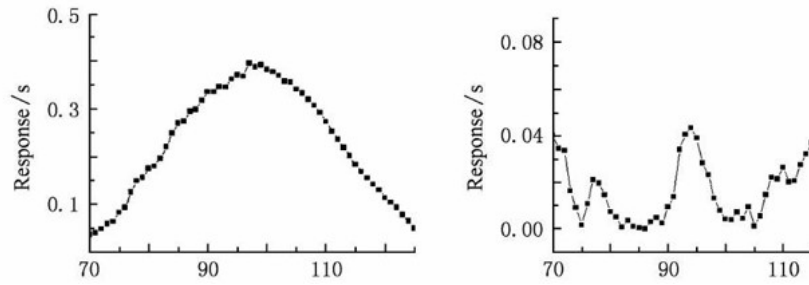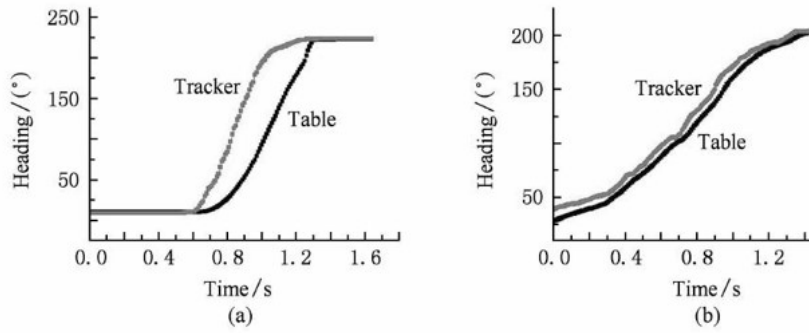
Evolution of Cartography from Cosmology and Cosmogony to GIS
in the Indian sub-continent [21]

Aim and scope

Indian subcontinent has been the cradle of knowledge from very ancient times. Spanning a history of over five thousand years, the region has seen evolution of knowledge systems, philosophies, reliogion, culture and language. As the scripts, languages and administrative systems evolved, the art and science of mapmaking also evolved with it. Ancient cartography in India can be rooted as old as 3rd century BC during the reign of Emperor Ashoka and the times of the Buddha. As Ashoka and the ancient rulers carried out expansion expeditions across all directions of the Indian Subcontinent, they created administrative maps, warfare maps, fort maps and other kind of diagrammatic record of spatial data.

Introduction

The principal concern of the history of cartography is the study of the map in human terms. As mediators between an inner mental world and an outer physical world, maps are fundamental tools helping the human mind make sense of its universe at various scales. Moreover, they are undoubtedly one of the oldest forms of human communication. There has probably always been a mapping impulse in human consciousness, and the mapping experience-involving the cognitive mapping of space undoubtedly existed long before the physical artefacts that now are called maps.

During the European Renaissance, however, especially from the sixteenth century onward, it is possible to trace an increasingly systematic attention to the maps of preceding centuries. The extent to which this represented genuine historical feeling for maps as independent documents should not be exaggerated, especially in view of the general surge of interest in the fifteenth and sixteenth centuries in classical geographical authors and of the fact that maps from the classical sources were valued as useful contemporary tools as well as vaunted as monuments of antiquity. Indian subcontinent has been the cradle of knowledge from very ancient times.

Spanning a history of over five thousand years, the region has seen evolution of knowledge systems, philosophies, religion, culture and language. As the scripts, languages and administrative systems evolved, the art and science of mapmaking also evolved with it. Ancient cartography in India can be rooted as old as 3rd century BC during the reign of Emperor Ashoka and the times of the Buddha. As Ashoka and the ancient rulers carried out expansion expeditions across all directions of the Indian subcontinent, they created administrative maps, warfare maps, fort maps and other kind of diagrammatic record of spatial data.

Ancient Era: Cartography or Non-Cartography? (2000 BC-1000 AD)

Ancient map making did not exist as a rational scientific discipline like European cartography in 1st century BC and 1st millennium AD in India.

It was more intertwined into the religion, culture, philosophical discourses like those in Jainism, Buddhism and religious diagrams of Vedic Hinduism.

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[21] Excellent preliminary report written by Bose Dipon, Kumar Riddhi, Taqi Mohammad (India), Sumaita Fatema Nur (Bangladesh).

Nandishwardvipa – the eighth continent of the Jain cosmos. Bas relief from Sagaram Soni temple, Mount Girnar, Saurashtra, Gujarat. Dated. Saka 1256 (A.D. 1199-1200)

This drawing by Wilford is among several early attempts by European scholars to render visually the descriptions of the cosmos of the various Hindu texts collectively known as the Purans

Although there are grounds to suppose that Indians produced maps for various purposes for roughly two millennia before the advent of the Portuguese – and possibly over a considerably longer period virtually nothing in the way of ancient cartography survives. In fact, apart from some incised potsherds of the second or first century B.C. that bear rough plans of monasteries and a few ancient sculptures depicting sacred rivers, there is no extant carto-graphic or cosmographic production of distinctly Indian stamp that can be unequivocally assigned to any date earlier than A.D. 1199-1200, the date of a Jain bas-relief representation in stone of the mythical continent Nandishwardvipa.

Francis Wilford was the first European to attempt to re-create a system representation of the systematic visual representation of the cosmographic conceptions of India, but this work (published in 1805) in Asiatic Researches, was carried when Indological research was still in its infancy. many of the conclusions he drew was still in its infancy. Many of the conclusions he drew from his studies with Brahman pundits, who always did not deal honestly with him, would not be taken seriously today. Among the shortcomings of Wilford's efforts was the persistent assumptions that most if not all of the place name in the Puranic texts did indeed have real world referents. No clear boundary was drawn between cosmographic ideas and more mundane terrestrial conceptions.

Ancient Hindu Mandala   *Sri Yantra*   *Tibetian Budhist Painting*

Iconogaphy on the realms of the Universe – Lokapurusa

Before drawing anything else, the realms of the universe were studied and taught in India by depiction of the human body. The cosmic man is a popular theme in late Jain painting. This example showcases the cosmological scheme of the world of the mortals (Adhaidvipa)– which is superimposed on the human body in an attempt to homologize the microcosm. The human body symbolism is sub-divided into the adhaloka (lower world), madhyaloka (middle world), and, urdhvaloka (upper world) each of which is represented differently. The depiction overall is thus acting as cosmic representation. From illustrations in contemporaneous manuscripts such as the Samgrahanisutra.
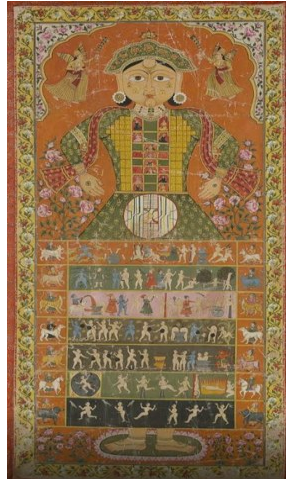
Lokapurusha

<u>*Spatial concepts and spatial relationship with culture*</u>
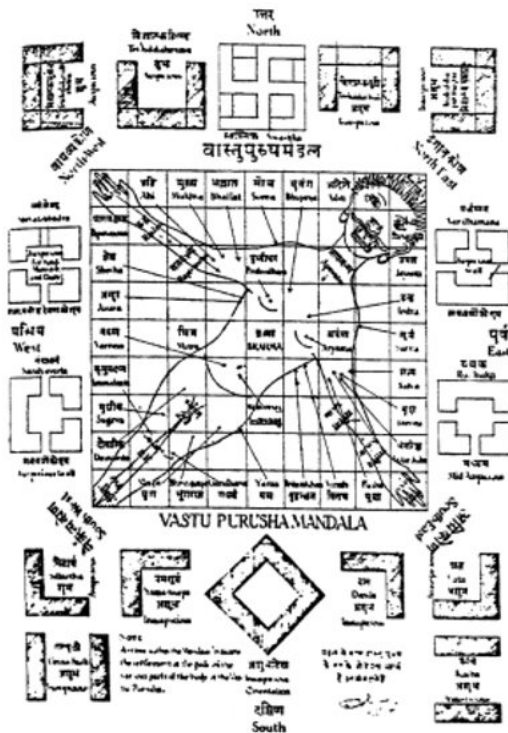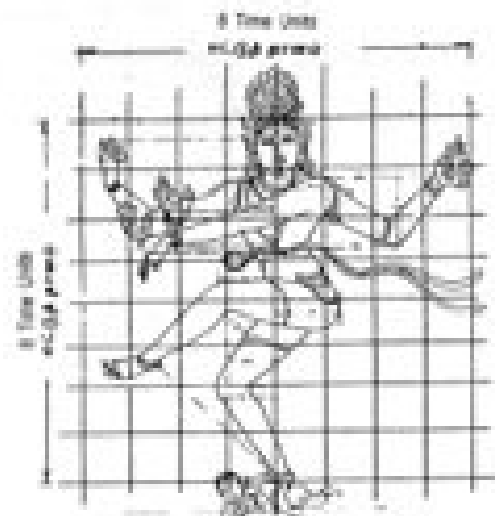
Vastu Purusha Mandala

VAASTU PURUSHA MANDALA

The Indian subcontinent by virtue of its large geographical span and extremely diverse culture adopted and refined many indigenous belief systems and spatial concepts. The belief of spatial realms like heaven and hell and earth and many zones in between were reflected in the maps and diagrams. As geographical exploration was limited to the administrative and political domain, terrestrial maps were not reflected in the scholastic texts of ancient India. Though terrestrial mapping is done through textual and poetic references instead of drawings.

Plan of Jaipur derived from Vaastu Purusha Mandala

Source: http://www.archinomy.com/sites/
default/files/case-studies/2011/int-2.jpg
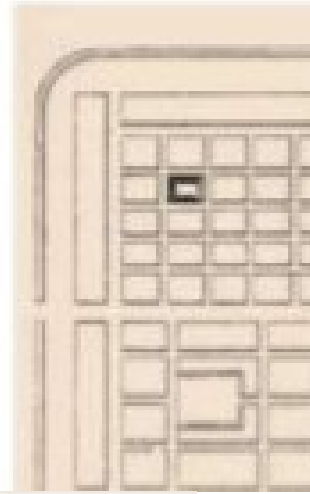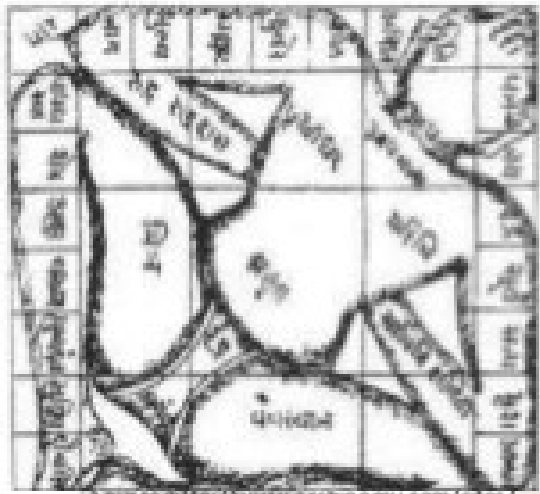
Vaastu purusha mand
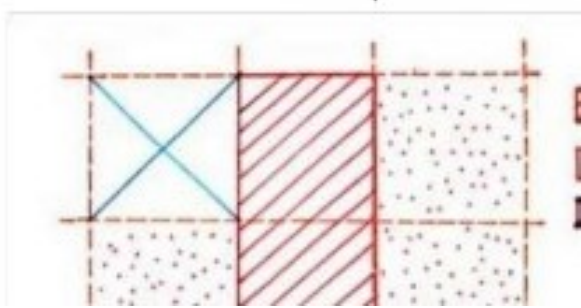
Jaipur Vaastu Purusha Mandala

It is a model of town planning, the first planned city in India. It is based on Hindu Systems of town planning and followed the principles prescribed in the Shastras. According to this, the site should be divided into grids, ranging from 2 x 2 to 10 x 10. Planned according to the piastra type of the layout which gives prominence to the Cardinal Directions. Thus, plan of Jaipur is a grid of 3 x 3 with gridlines being the city's main streets. Central axis of the town was laid from East to West, between the gates of the Sun (SurajPol) and the moon (ChandPol). This was crossed by two roads by right angles dividing the town into nine almost squares, almost equally sized box, which were further subdivided by sub lanes. The Mandala could not be complete on the North West due to the presence of the hills. On the other hand, in the South East, an extra square has been added, that plugged the gap between the city and the eastern hills.

- On the other hand in the **SE** an **extra square** has been **added** that **plugged the**
and the eastern hills.
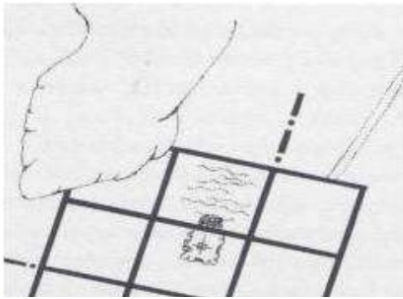
Process of the Plan of Jaipur
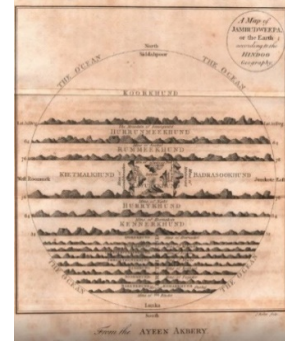
*A Map of the Earth according
to the Hindu Geography*

Indian cosmography – vedic cosmology

In a map of the Earth according to Hindu Geography and Indian cosmography, the world is divided into seven concentric island continents, separated by the seven encircling oceans, each double the size of the preceding one. Could it be, that the scriptural reference of Jambud weep, actually originated in a time when the Entire Earth was ONE whole Continent and not broken up into different landmasses.

Researchers have confirmed that as the continents of the earth today were actually one single mass many, many years ago, these descriptions in scriptures clearly define an island of gigantic proportions covering this entire globe and it is more than likely that they refer to one of the super-continents that have existed in our pre-history.

Mapping of cultural landscapes on 2D medium

Ancient cities like Varanasi (oldest Hindu pilgrimage city, 5000 years old) and Gaya (oldest Buddhist pilgrimage town,2000 years old) have been mapped by local artists and painters who got the knowledge of indigenous cartography from their forefathers.

Varanasi Map   *Pictorial depiction Hindu Pilgrimage*

Since scientific dataand analysis behind such maps are missing, such maps are often considered outside the domain of Western cartographic and mapping disciplines. A close visual analysis of such maps will depict that a lot of spatial and non-spatial data was represented in them. Relational information of the rivers, stories behind them, parables, flora and fauna were depicted in them.
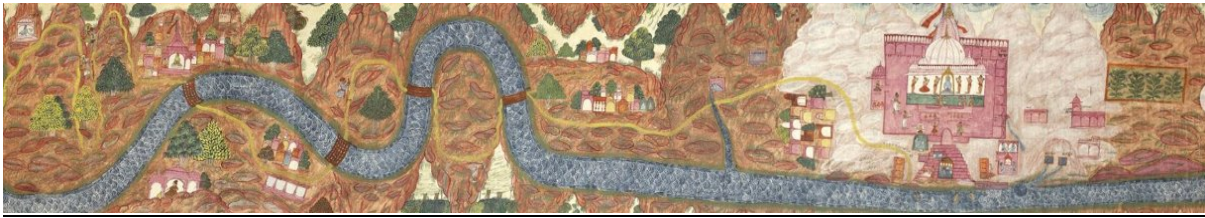
Route map of Ganges

Depiction of temples, palaces, riverscan, i.e. early photogrammetry?

This route map depicts the river Ganga and one of its chief headwaters, the Alakananda, as seen by the devotee making a pilgrimage as far as the shrine at Badrinath in the Garhwal Himalayas. The Himalayan topography and relief are depicted quite accurately along with the path of Ganga river and temples in the foothills- which can be attributed to temple towns of Haridwar and Rishikesh. In keeping with such route maps, features on the left bank of the river are depicted upside down. The scroll is plentifully supplied with inscriptions, naming sacred places, villages, mountains and trees. The path is conspicuously painted yellow all the way along the scroll, and travelers and pilgrims are seen following it up and down mountainsides and over the bridges across the rivers. Many are on foot and equipped with staves, though the wealthy are carried in hill doilies or jam-pans, while two men carry women in panniers on their backs. The river and its tributaries are depicted in brilliant blue and white basket patterns, while the hillsides and mountains are in shades of mauve and brown (white for the highest mountains) set off by the brilliant depiction of the various trees in traditional Rajasthani style and by the numerous shrines. Badrinath is one of the four great religious sites at the extremities of India along with Dwarka, Puri and Ramesvaram, as established by the great sage Sankaracarya in the ninth century. In keeping with this foundation, the chief priest or Rawul is always a Nambudiri Brahmin from Sankaracarya's homeland of Kerala. The main road ends in Badrinath where the pilgrims bathe in the river beside the temple of Vishnu, who is seen enshrined and being worshipped. Nonetheless the artist has gone to considerable trouble to include all the sacred spots in the immediate vicinity, hence accurate information about them did exist.

Ancient Hindu mapping of the holy river Ganges and the Himalayas compared with GIS

DEM

GIS model

Entry to Ganges
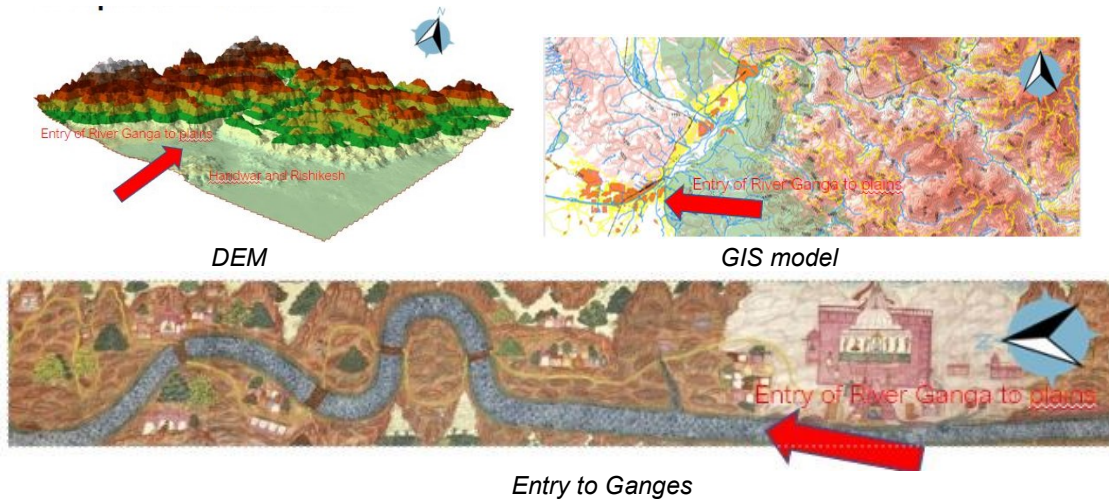
Ancient religious maps depicting pilgrimage routes in the Himalayas along with temples, towns and terrain are very close to accurate depection of GIS based maps and digital terrain models (DEM) done on ArcGIS in 2020 AD. The GIS terrain model developed by Dipon as a part of his Urban Design and Urban Planning studio can be used to compare the Upper Ganges valley along with the position of Haridwar and Rishikesh at the foothills and high mountains above.

Religion, culture, philosophy, administration intertwined

The evolution from early cosmological representations of the 'World of Mortals', to pictographic depictions of ritual landscapes and sacred pilgrimage sites, through to the evolution of cartography is testament of the diverse, competing and global interests and influences – religious, economic and political - which have contributed to the perception of 'India' as it is understood it today.

Mortals of World

Jain and Hindu cosmological representations

The journey commences with Jain and Hindu cosmological representations, through to painted hangings depicting sacred rivers and pilgrimage sites, and ultimately to the transition of cartographic depictions of the ancient European conception of the subcontinent. The exhibition continues with the first vaguely accurate maps of India done in the wake of Vasco da Gama's arrival in 1498, documents the evolution of map making as part of the military contestation for supremacy by various European powers and ultimately the cartographic consolidation of India through the map makers of the British Raj.

Satrunjaya Patha:

Large in size and rich in detail, these painted maps depict the pilgrimage circuit at the sacred Jain site of Satrunjaya (modern town of Palitana in Gujarat). Such compositions are therefore generally referred to as Satrunjaya Pata. The key purpose of these paintings is to provide a panoramic view of the key shrines, the pilgrimage route and details of significant features and episodes along the devotee's path. The artist depicts the topographic context of Satrunjaya hill with its two ridges. The first ridge is dominated by the main temple complex of Adinatha. The other ridge is the setting for nine smaller temple complexes patronized by Jain merchants. The painters depict the pilgrimage route from the point of view of the devotee's experience rather than a topographic expression of the site; despite this, these examples show strong geomorphic coherences.

Beginning of hand drawn plans – temples

Right after the pilgrimage routes were drawn and distributed in the country, plans of the religious points started to be drawn. Hand drawn plans so detailed that fortified walls, courtyards, rectangular pattern of the

plots, main entry points and the material of the walls were explicitly showcased. This particular plan is of the Shrinathji Temple at Nathdwara. Composed from a series of shrines, palaces and service rooms, within a bastioned boundary wall. With one main gate at the heart of the town, the complex follows the architectural tradition of a large Rajasthani mansion.

Satrunjaya Patha Plan

Shrinathji Temple Plan

Plan of West Bengal

Hand drawn maps: Hooghly-Chinsura, West Bengal:

Cityscapes were also hand drawn. This plan grants a detailed insight into the formation of a European factory in India. While there were several European-governed cities in India, most European settlements consisted of such compact, commercial outposts built on land leased or rented from Indian rulers. The plan depicts Chinsura as it appeared in 1721, and shows a variety of facilities, such as the Governor's house, an accounting office, warehouses, military barracks, residences and docking quays, all enclosed enclosed by a wall. It is interesting to learn that each hand drawn map even of the states like West Bengal, Tamil Nadu, etc. is extremely accurate as confirmed by the cartographers later.

Plan of Kochi – Town in South India:

Plan of Kochi

The fascinating map sheet features two different plans of Cochin (Kochi). The larger plan depicts the city as it appeared at the end of the period of Portuguese hegemony. The smaller plan (below) was used by the minister and ethnographer Phillip Baldaeus to depict the Dutch plans for altering the city following their seizure of Cochin in 1663. Cochin was one of the most important trading and cultural centres in all of India. It became the nucleus of the Indian spice trade, following the destruction, due to flooding, of the nearby port of Muziris (near modern Kodungallur) in 1341. While the Raja of Cochin continued to exercise nominal authority, from the beginning of the 16th Century, Cochin was controlled by the Portuguese. During this era, as shown on the plan, the city's walls expanded to take up the entire tip of the peninsula, featuring many urban blocks occupied by trading rooms, warehouses, ecclesiastical institutions and grand residences. On January 8, 1663, Dutch Admiral Rijckloff van Goens captured Cochin. As shown on the smaller plan below, the Dutch decided to extensively remodel Cochin, condensing the urban area and surrounding it with more robust fortifications in line with the latest standards of engineering.

Plan of Pondicherry:

This exceptionally large military engineer's plan depicts Pondicherry, which founded as the capital of French India in 1674 and developed into the finest European-planned city in India. This city is depicted as it appeared in 1741, during the height of its prosperity. Focusing tightly in on the walled city, the exactingly drafted and finely coloured plan is adorned, in the lower right quadrant, by an elegant rococo cartouche. The map's grand appearance suggests that it was intended as a presentation piece for a senior French official, although, curiously, it is unsigned. Pondicherry was then enveloped by walls, graced by broad tree-lined streets and many beautiful buildings and public squares.

Thirty-eight key sights are identified on the map, corresponding to the 'Renvois' (Reference), located within the rococo cartouche. Notably, Pondicherry was divided into four districts: French Quarter was located towards the waterfront to the south (left) of the Fort, while the north (right) was the New French Quarter. Inland from this district was the Indian Town, home to the vast majority of the city's residents, while New Extension, comprising the southwest portion of the town (the upper left), was built up only recently. Unfortunately, the city as depicted here was almost totally destroyed by the British, following their seizure of Pondicherry in 1761. Although the city was subsequently rebuilt, it never regained the same splendour.
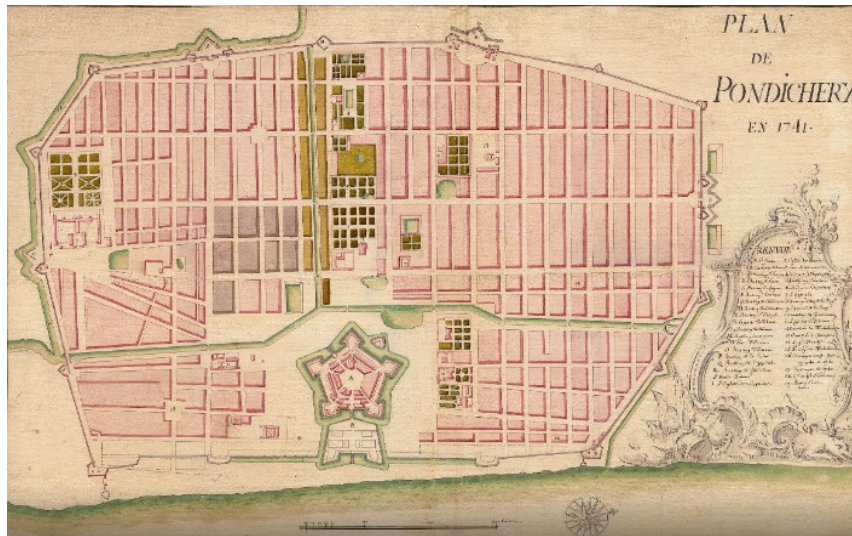
Plan of Pondicherry

European perspectives on maps of India 1400-1900 AD
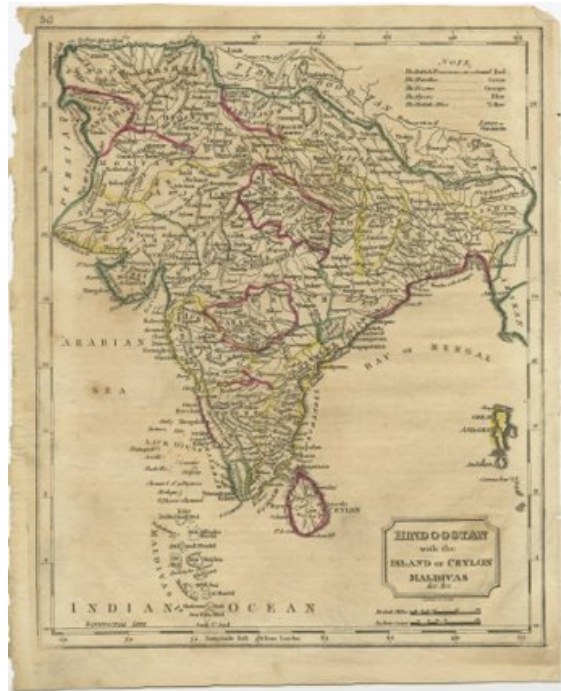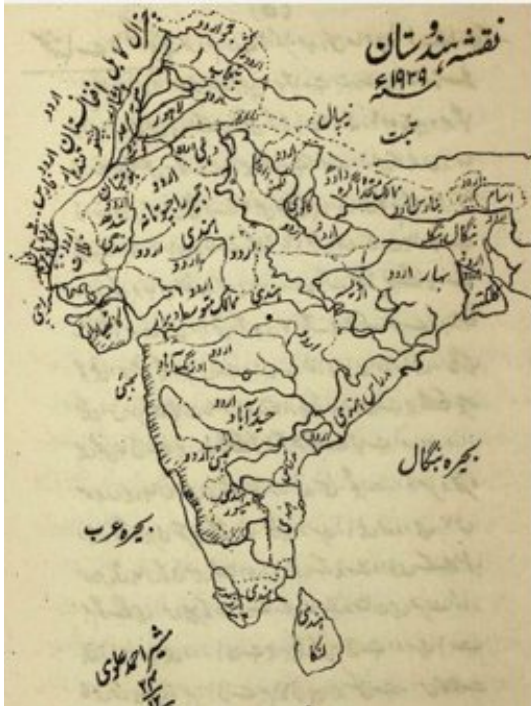
Maps of Mughal India

Apart from map catalogs and the work by Pulle, the only books devoted exclusively to the pre-modern mapping of India are by Gole. The first other works, Early Maps of India, is concerned entirely with European maps from the time of Ptolemy up to the end of the eighteenth century. That initial survey, however, is superseded by a richly illustrated production, India within the Ganges, that, while still emphasizing the voluminous corpus of European cartography, does contain a brief opening chapter on indigenous maps, five of them illustrated. later work edited by Gole is Maps of Mughal India, which reproduces an atlas commissioned by Colonel Jean Baptiste Joseph Gentil, an adviser to the Nawab of Oudh (Awadh), and drawn in 1770 by three Indian artists relying mainly on the gazetteer portion of the Ain-i Akbari (Institutions of Akbar), an important Indian text (in Persian). This atlas is a valuable and hitherto little noticed work.

From religious philosophy to European trade maps

While the religious philosophies were developing non-terrestrial maps inside the Indian subcontinent, the European traders and explorers started drawing various depictions of trade routes to India across the Mediterranean, Arabian Sea and the Indian Ocean. This led to the dawn of modern cartography and hold some key records of 17th-19th century mapping explorations by Europeans.

European Trade Maps

Modern Cartography

The cartography of India begins with early charts for navigation and constructional plans for buildings. Indian traditions influenced the Tibetan and Islamic traditions, and in turn, were influenced by the British cartographers who solidified the modern concept into India's map making. Joseph E. Schwartzberg (2008)

proposes that the Bronze Age Indus Valley Civilization (c. 2500–1900 BCE) may have known "cartographic activity" based on several excavated surveying instruments and measuring rods and that the use of large-scale constructional plans, cosmological drawings, and cartographic material was known in India with some regularity since the Vedic period (1st millennium BCE). Native Indian cartographic traditions before the Hellenistic period remain rudimentary. Early forms of cartography in India included legendary paintings; maps of locations described in Indian epic poetry.

Development of Indian cartography in early 1700s

Early Indian cartography showed little knowledge of scale, the important parts of the map were shown to be larger than others (Gole 1990). Indian cartographic traditions also covered the locations of the Pole star, and other constellations of use. These charts may have been in use by the beginning of the Common Era for purposes of navigation. By the early 18th century "these framings began to merge this was a manifestation of the Enlightenment's encyclopaedic mentality, which produced massive tomes intended to present all available knowledge to their bourgeois readership. By the mid to late 18th century the British had gained control of the Mughal and southern regions creating the geographic idea of the subcontinent, and our modern idea of India as a unified geographic entity was solidified by Renell's depiction of it on his maps. It was within this milieu, and with the desire for military and economic control of India, that Rennell's survey of the region began and was continued by the Great Trigonometrical Survey of India and its modern Survey.
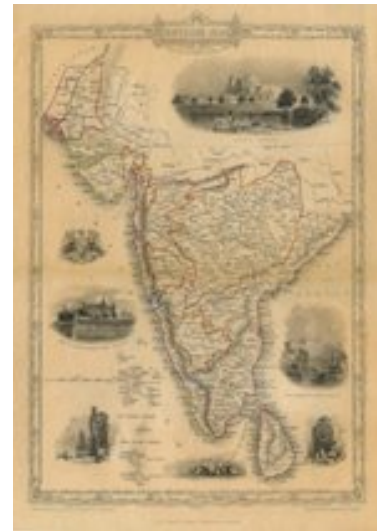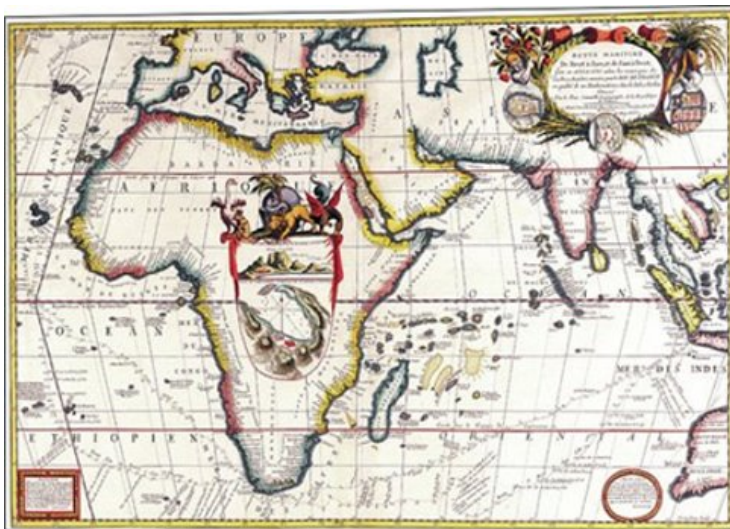
Cartographic map of ancient India – India during British Colonization

James Rennell: the father of the Indian survey

Major James Rennell (1742-1830) became a midshipman at age 14, received training in surveying in the Royal Navy, joined the East India Company in 1763, was the first Surveyor General of Bengal (1767-1777), and carried out the first comprehensive geographical survey of much of India. The survey was a large massive undertaking, which mapped parts of India at a greater detail than many European countries had been mapped (Goss, p. 246). His surveying led to The Great Trigonometrical Survey of India which began in 1802 (See the exhibit section: "The Survey of India"). He is most known for his Bengal Atlas of 1779 and Memoir of a Map of Hindoostan (1782).

A Bengal atlas: containing maps of the theatre of war and commerce on that side of Hindustan, 1781

A map of Bengal, Bahar, Oude & Allahabad : with part of Agra and Delhi, exhibiting the course of the Ganges from Hurdwar to the sea, 1786

A map of the provinces of Delhi, Agrah, Oude, and Ellahabad: comprehending the countries lying between Delhi and the Bengal-provinces, 1786

A map of the north part of Hindostan or a geographical survey of the Provinces of Bengal, Bahar, Awd, Ellahabad, Agra and Delhi, 1794

Renell continually updated his maps for accuracy and added new geographical information, using indigenous maps and drawings as sources for his maps of the Punjab region. His cartographic methods included gleaning information from earlier maps, measuring distances along roads, establishing the coordinates of control points, and then creating a "graticule" or grid to create his maps. Rennell's maps were of such accuracy and quality that they were used well into the 19th century.

Consolidation of cartography with surveyors of British India: the great trigonometrical survey
The Great Trigonometrical Survey was a project which aimed to measure the entire Indian subcontinent with scientific precision.

- ❑ It was begun in 1802 by the British infantry officer William Lambton, under the auspices of the East India Company.
- ❑ Under the leadership of his successor, George Everest, the project was made the responsibility of the Survey of India.
- ❑ Everest was succeeded by Andrew Scott Waugh.
- ❑ Then after 1861 the project was led by James Walker, who oversaw its completion in 1871.

Among the many accomplishments of the Survey were the demarcation of the British territories in India and the measurement of the height of the Himalayan giants: Everest, K2, and Kanchenjunga (near to the north border of the British administration).

The Survey had an enormous scientific impact as well, being responsible for one of the first accurate measurements of a section of an arc of longitude, and for measurements of the geodesic anomaly which led to the development of the theories of isostasy.

European colonial and British administrative maps
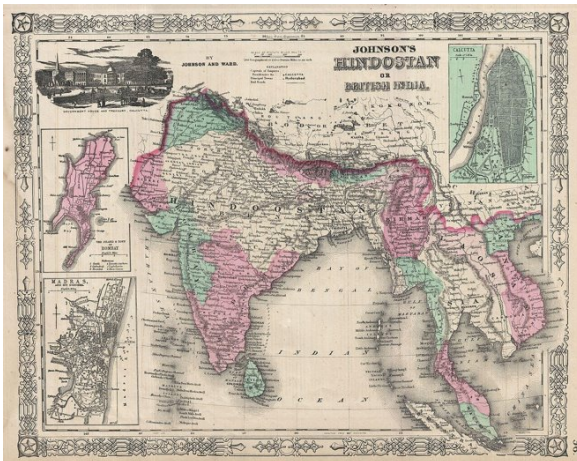
British Administrative Map
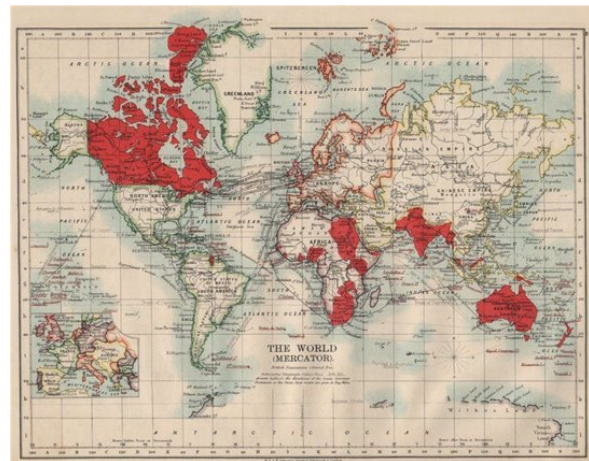
European Colonial Map
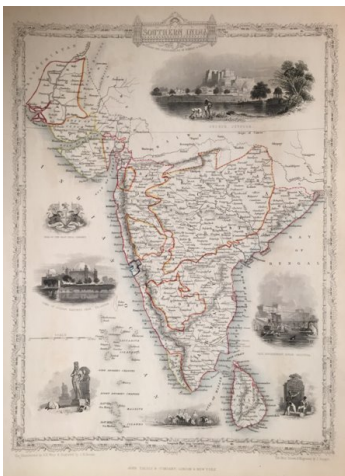
Cartography during British India

Surveyors of India

Trigonometrical Survey of India

City planning, British port towns – 19th century maps of Indian subcontinent

19th century maps of Indian subcontinent

Surveying of India and surveyor general of India

The Survey of India is India's central engineering agency in charge of mapping and surveying. Set up in 1767 to help consolidate the territories of the British East India Company, it is one of the oldest Engineering Departments of the Government of India. Its members are from Survey of India Service cadre of Civil Services of India and Army Officers from the Indian Army Corps of Engineers. It is headed by the Surveyor General of India. At present, Survey of India is headed by Lt Gen Girish Kumar.

The history of the Survey of India dates back to the 18th Century. "First modern scientific survey of India" was undertaken by W. Mather in 1793–96 on instructions of Superintendent of Salem and Baramahal, Col. Alexander Read. The present Dharmapuri district, Krishnagiri district and North Arcot in western Tamil Nadu were then called Baramahal.
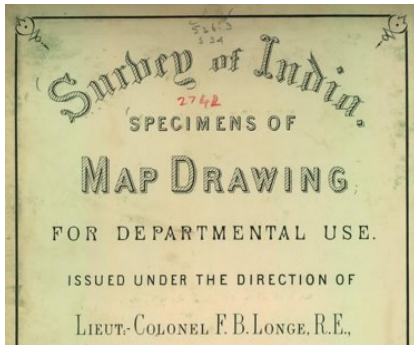
Survey General of India Dept.
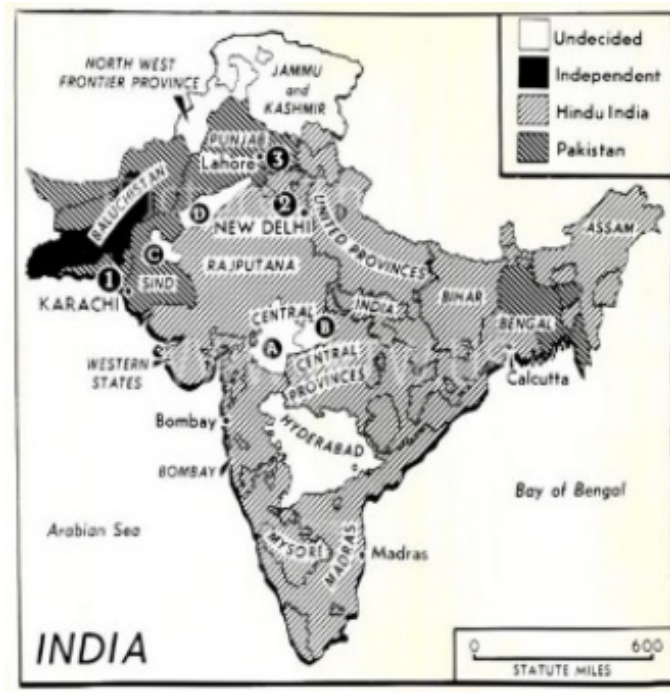
How things looked right after Partition: a news map from the archives of the Chicago Sun Times

Post-colonial developments in the mapping and survey technology (Post independence 1947)

Post-independence, Survey of India, (Surveyor General of India, 2020) was entrusted with the responsibilities to look out for the developments in the surveying and mapping approaches. This task was particularly challenging due the huge influx of refugees, communal riots, severe food shortage, extreme poverty, hunger, and continuous tension along the boundaries. The new maps were needed to assist the policy makers and administrators to solve these emerging problems in India. (Mondal, 2019). Like the rest of the world in India as well maps became more abundant due to improvements in printing and photography that made production cheaper and easier. Airplanes made it possible to photograph large areas at a time making it easier to cover larger areas with more precision.

 Survey of India then started working on developing various types of topographical, geographical and several public series maps. These maps were covering the whole India at different scales. (Rao, 2017) Since then all types "Scientific Surveys" i.e. "geodetic and geophysical surveys, seismicity and seism-tectonic studies, environmental and disaster management, participation in Indian scientific expeditions to Antarctica, glaciology programs and other projects related to digital cartography and digital photogrammetry" have remained as the primary responsibility of Survey of India. (Rao, 2017) Survey of India is also engaged in the demarcation of the boundaries of India with neighboring countries and the depiction of this on map and as adviser to Government of India in the demarcation of inter-state boundaries. (Rao, 2017).
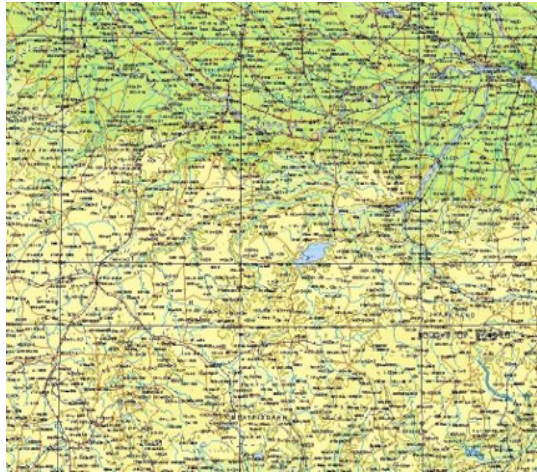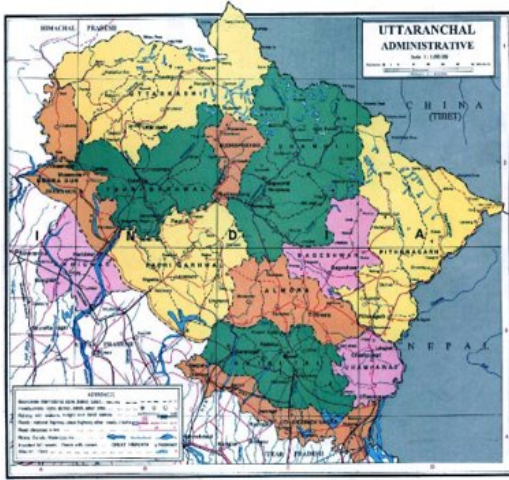
State Atlas Contain more than 33 different themes   National level digital data on 1:1 million

The requirement for accurate and precise maps for planning and governance led to the establishment of the National Atlas Organization in 1954, which was renamed as the National Atlas and Thematic Mapping Organization (NATMO) in 1978. Based on analogue and digital data, various thematic maps especially detailing physiography, drainage, climate, hydrology, soil, vegetation, agriculture, industry, minerals, settlements, transport as well as political and social criteria were produced by NATMO. Atlases and planning maps at different scales: e.g., the city maps, the district maps, the state maps, are also prepared by NATMO. (Rao, 2017).

India in the modern age of Remote sensing and GIS

In 1974, another significant organization, the National Remote Sensing Agency (renamed as National Remote Sensing Centre in 2008) was established as India entered space research, mainly aerial photography, and satellite remote sensing. This is the nodal agency for the procurement and distribution of aerial photos and satellite images. The Indian remote sensing satellite (IRS) program (Navalgund & Kasturirangan, 1983) was a major step forward in the overall program for using space technology for defined applications in India. The principal elements of this program were to design, develop and deploy a three-axis stabilized polar sun-synchronous satellite carrying state-of-the-art payloads using charge coupled devices for acquiring images of the earth.

To establish and routinely operate ground-based systems for spacecraft control, data reception and recording, processing, generation of data products, analysis and archival, and to use Its data either alone or in conjunction with supplementary and complementary data for applications in selected resources surveys. (Navalgund & Kasturirangan, 1983). The Program started with the experiment on detection of coconut root wilt disease from a helicopter-mounted multi-spectral camera system in 1970 has matured into a fully operational program. It is self-reliant in every aspect of the technology and applications.

Indian Earth Observation program started from Bhaskara-1 satellite (June 1979) which had two types of sensor systems viz. television camera and microwave radiometer. Imageries of Bhaskara at 1 km spatial resolution helped in carrying out land use, forestry, and geological studies. Then SAMIR payload measured brightness temperature in 19 GHz and 22 GHz for study of ocean-state, water vapor, liquid water content in the atmosphere, etc. Bhaskara-1 was followed by Bhaskara-2 (Nov. 1981) with improved SAMIR instrument.

The first operational remote sensing satellite IRS-1A launched on March 17, 1988 had two types of payloads with Linear Imaging Self Scanned imaging (LISS-1 and LISS-II). IRS-1A mission was followed by IRS-1B and subsequently IRS-P2, IRS-1C, IRS-1D were flown with improvement as per several user needs and requirements.

Currently, thirteen operational satellites are in Sunsynchronous orbit–RESOURCESAT-1, 2, 2A CARTOSAT-1, 2, 2A, 2B, RISAT-1 and 2, OCEANSAT-2, Megha-Tropiques, SARAL and SCATSAT-1, and four in Geostationary orbit- INSAT-3D, Kalpana & INSAT 3A, INSAT -3DR.

Varieties of instruments have been flown onboard these satellites to provide necessary data in a diversified spatial, spectral, and temporal resolutions to cater to different user requirements in the country and for global usage.

The data from these satellites are used for several applications covering agriculture, hydrology, urban planning, rural development, mineral prospecting, environment, forestry, ocean resources and disaster management. (Misra, 2017).
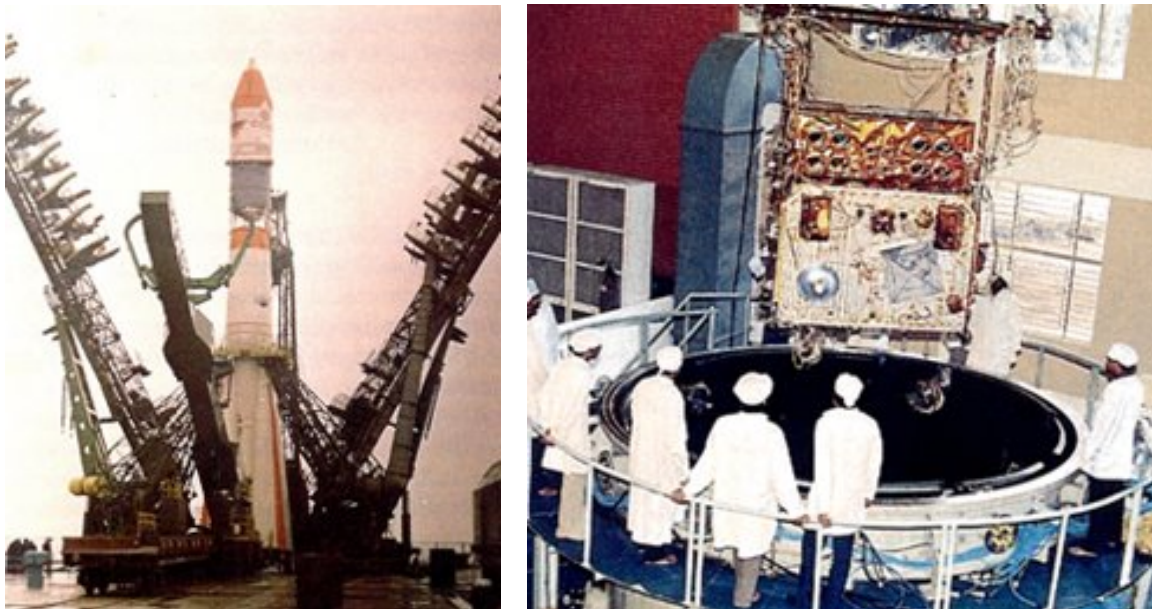
The "VOSTOK" ready for Lift-off with IRS-1A on board (March 17, 1988)

2 IRS-1A being lowered into Thermovac Chamber for Simulation
Tests at ISRO Satellite Centre, Bangalore (1987-88)
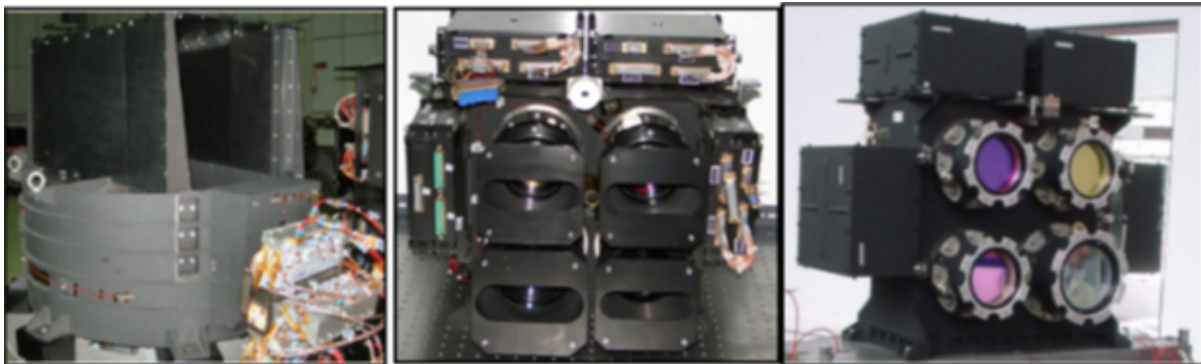
ISS-4, LISS-3 and AWiFS cameras of resourcesat-2

| AWiFS (56m) | LISS-3 (23m) | LISS-4 (5.8m) |
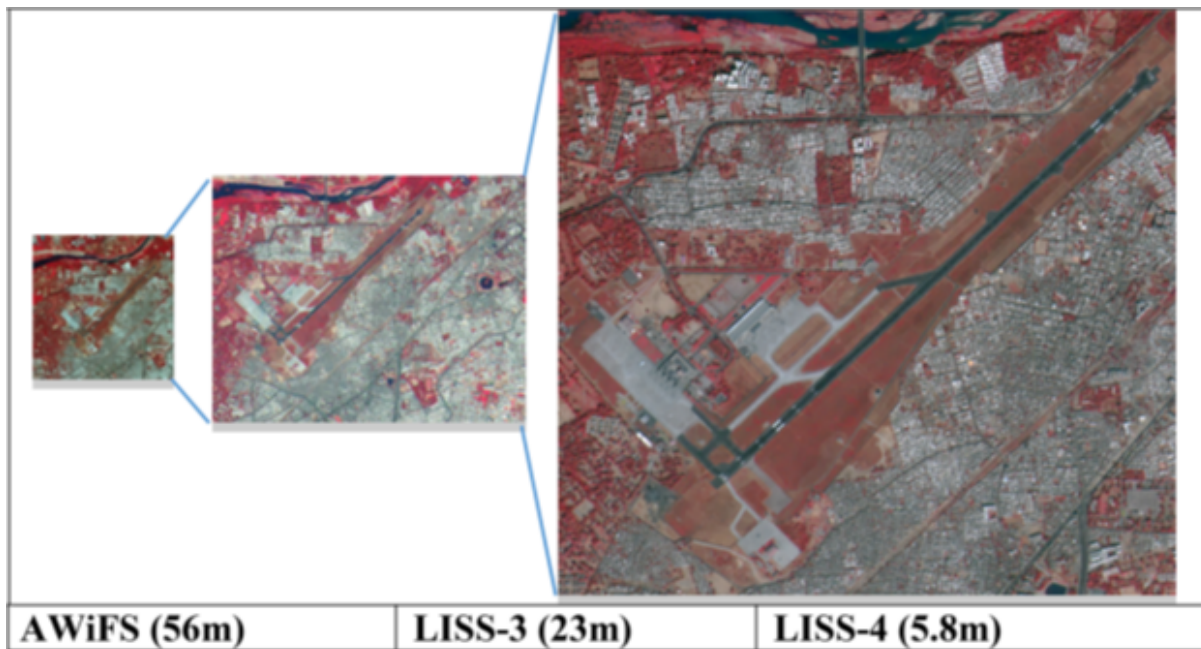
Three tier imaging by resourcesat-2A, AWiFS (56 m), LISS-3 (23 m), LISS-4 (5.8 m)

Since the advent of indigenous satellite systems, mainly Indian Remote Sensing Satellites (IRS), mapping and cartography in India has significantly entered digital mode. High resolution Satellite images along with existing analogue maps are now used for planning, research, defense, and administration. The IRS series satellite images are also used by different countries for similar purposes. Since 2005, different series of Carto-Sat satellites have been launched by ISRO especially for cartography and mapping.

Continuing the legacy from its colonial rulers, India, therefore has maintained the tradition of high precision and accuracy in mapping during the postcolonial period. However, to uphold national security as well as to provide geo-spatial data and information for scientific research, maps produced by these agencies are now available in two different series i.e., the Defense Series and the Open Series. Under National Map Policy, 2005, Defense Series Maps (DSM) are prepared on Everest/WGS-1984 datum, polyconic or UTM (Universal Transverse Mercator) projection with scales: 1:250.000; 1:50.000 and 1:25.000 (Govt. of India, National Map Policy 2005).

These maps contain classified information and allowed to access by the civilians based on the guidelines framed by Ministry of Defense, Government of India (Govt. of India, National Map Policy 2005). Open Series Maps (OSM), on the other hand, are prepared on WGS 84 datum and UTM projection and are freely available for Indian citizens. As per National Map Policy, 2005, Survey of India will be the sole authority to prepare and publish OSMs for developmental activities in the country.

In this new era of digital cartography and mapping in India, several web portals and data sharing platforms are now available for easy access, networking and sharing geo-spatial data and information. The National Data Sharing Accessibility Policy (Govt. of India, NDSAP 2012) was formulated in 2012 to ensure the sharing of data on both analogue and digital platforms for developmental activities (Survey of India, Annual Report 2016-2017).

The National Topographic Database was generated by Survey of India.

Three important spatial web services

Bhuvan: Indian Geo Platform of ISRO, India-WRIS: Water Resources Information System of India and National Information System for Climate & Environment Studies (NICES) are now available. Bhuvan was designed for the earth observation service, IWRIS for "Single Window Solution" to all water related data and NICES for climate and environmental impact related assessment. Beyond mapping and digital database generation, India has already ventured in the field of navigation. GAGAN – GPS Aided GEO Augmented Navigation an Indian Satellite Based Augmentation System and IRNSS-Indian Regional Navigation Satellite System Program are the two flagship programs initiated by Indian Space Research Organization. GAGAN has been designed for aviation purpose and it is presumed that in future general surveys for rectification of cadastral maps will be carried out using of this system (GNSS Newsletter, July 2015). On the other hand, IRNSS is an indigenously developed satellite-based navigation system for the regions in and around India. With the development new technologies, India shows her potential to be one of the leaders in survey, mapping, and geo-spatial database development. (Mondal, 2019).
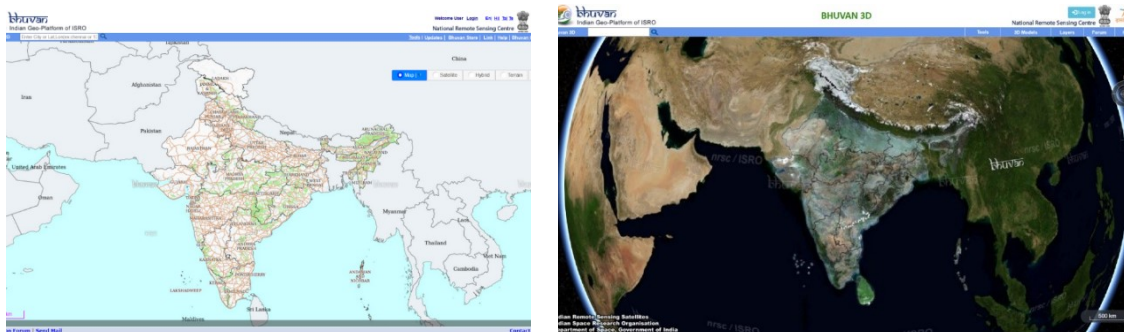
Bhuvan 2D and 3D, Indian Geo Platform of ISRO

Therefore since 1947, mapping India has been dedicated to nation building [22].

❑ Maps are continuously being used for defence, administration, demarcation of intra-state, inter-state and international boundaries, resource availability and use, analysis of socio-economic conditions of the people, regional pattern of demographic dynamics, urban planning, development, etc.

❑ Satellite images, digital cartography and Web portals are being used to update data and information not only by the citizens of India, but also by the neighbouring countries.

❑ Maps are part of the curriculum in schools and colleges: cartography and mapping science are two significant areas of research in India

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[22]

n.d. *Ancient History Encyclopedia.* https://www.ancient.eu/mapselect/.
n.d. *Decode Hindu Mythology.* http://decodehindumythology.blogspot.com/2012/02/jambudweep-global-island.html.
2017. "Geosciences."
n.d. *GIS and Remote sensing.* https://www.nbfgr.res.in/en/page/gis.
n.d. *Google Arts and Culture.* https://artsandculture.google.com/exhibit/cosmology-to-cartography-sacred-maps-from-the-indian-subcontinent-kalakriti-archives/1wLSzO0BWWZ3Jw?hl=en.
n.d. *Google Arts and Culture.* https://artsandculture.google.com/exhibit/cosmology-to-cartography-early-players-in-the-indian-subcontinent/EwKigcL5BRCTKw.
n.d. *IN.gov.* https://www.in.gov/gis/.
n.d. *Indian Institute of remote sensing.* https://www.iirs.gov.in/.
n.d. *Scroll.in.* https://scroll.in/article/722369/the-changing-map-of-india-from-1-ad-to-the-20th-century.
n.d. *Slideshare.* https://www.slideshare.net/saumyakohli/architecture-and-planning-of-jaipur.
n.d. *The Hindu.* https://www.thehindu.com/features/friday-review/history-and-culture/mapping-the-past/article6725104.ece.

PART V

GIS for Wetland Assessment and Conservation – Experience in Latvia [23]

Applications

- ❑ Mapping;
- ❑ greenhouse gases monitoring;
- ❑ biotope restoration.

Data Sourcing – Arsenal flying laboratory

Airborne hyperspectral remote sen...

ARSENAL covered spectrum

RADIO-WAVES	INFRARED	VISIBLE LIGHT	UV	X-RAYS	GAMMA RA...

12000   750   390   280

Thermal infrared sensor
3700-5000 nm

- Objects radiating heat

Mid-wave infrared sensor
3000-5000 nm

- Detection of invasive species
- Detection of oil spills
- Mapping of miner resources
- reserach needs

Short wave infrared sensor
950-2450 nm

- Water pollution
- Plant species
- Mapping of miner resoources

Light detection and ranging sensor
1065 nm

- 3D terrain/surface
- high precision mapping

Long wave infrared sensor
8000-12000 nm

- Objects radiating heat
- For industrial sector and

High resolution RGB camera
390-720 nm

- high resolution areal images

The visible and near infrared sensor
380-1050 nm

- Surface materials
- Classification of vegeta-

Ultraviolet sensor
280-375 nm

- Water pollution
- Estimation of chlorophyll

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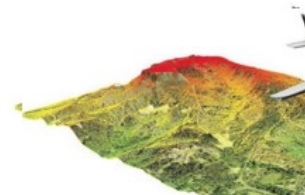
[23] Excellent preliminary report written by Anete Egle (Latvia).

Hyperspectral data use for the study of land and Baltic Sea
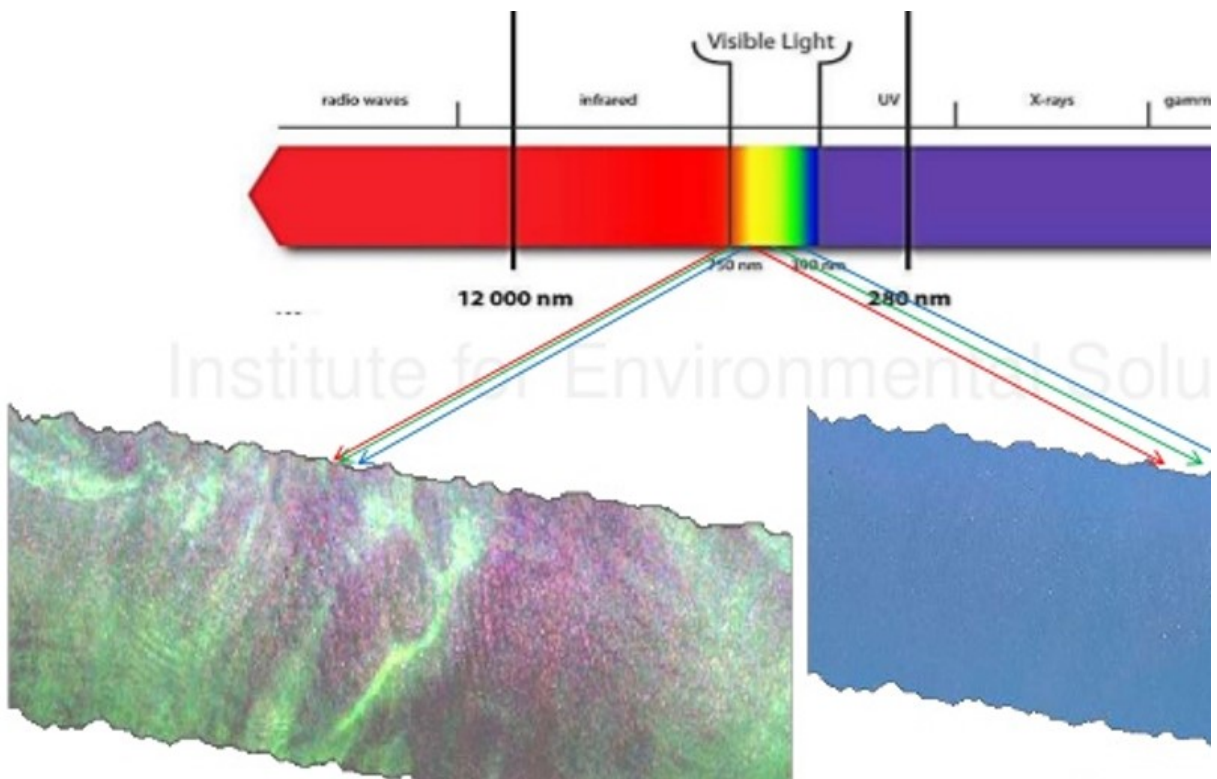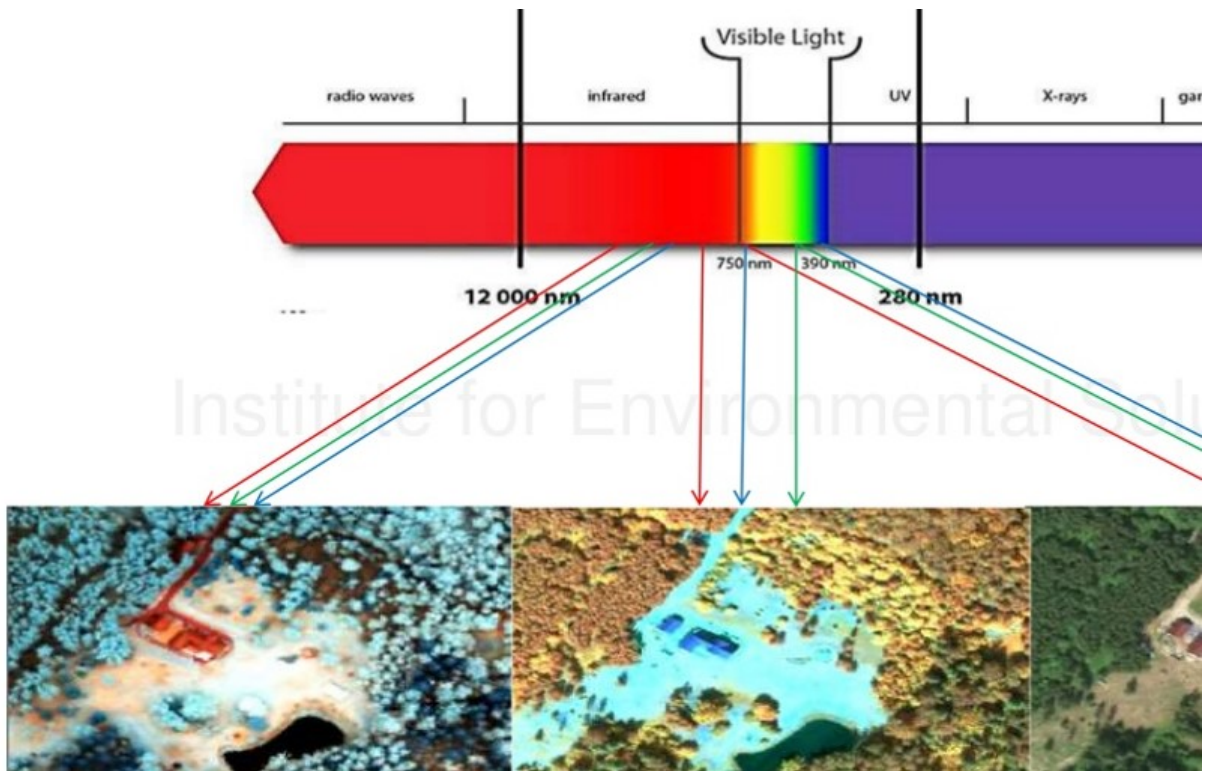
Greenhouse gases (GHG) monitoring

Four different wetlands in Latvia selected as research project locations:

- Madiešēnu un Namītēnu wetland "Augstroze";
- Sudas-Zviedru wetland in Gauja National Park;
- Wetland in "Engures ezers";
- Wetland in Slitere National park.

GHG monitoring: data pre-processing

Pre-processing of data at Sudas-Zviedru wetland territory.

- project polygon;
- data mosaic of high resolution hyperspectral sensor;
- data mosaic of high-resolution visual camera.
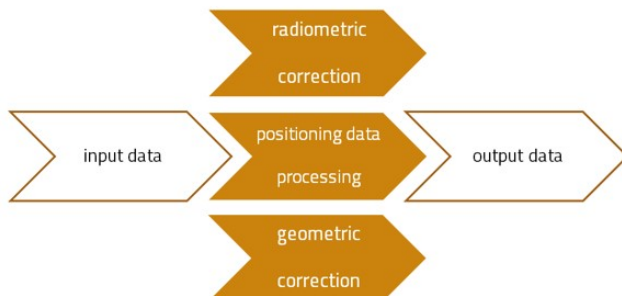
GHG monitoring: reference data for surveying
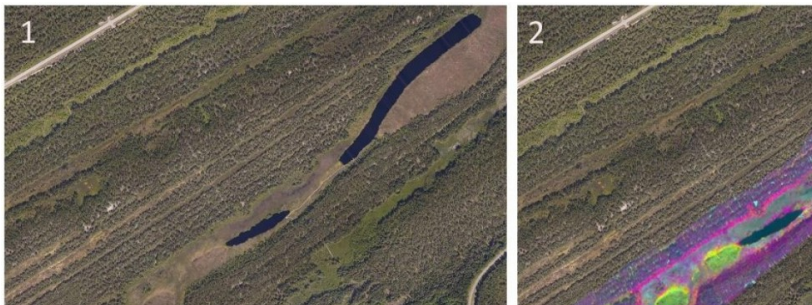
Maps from Sliteres National park used for site surveys. GEST (Greenhouse-Gas Emission Site Types) methodology was apllied to classify different types of vegetation:

- ❑ high-resolution orthoimage;
- ❑ spectral map.

GHG monitoring: data analysis
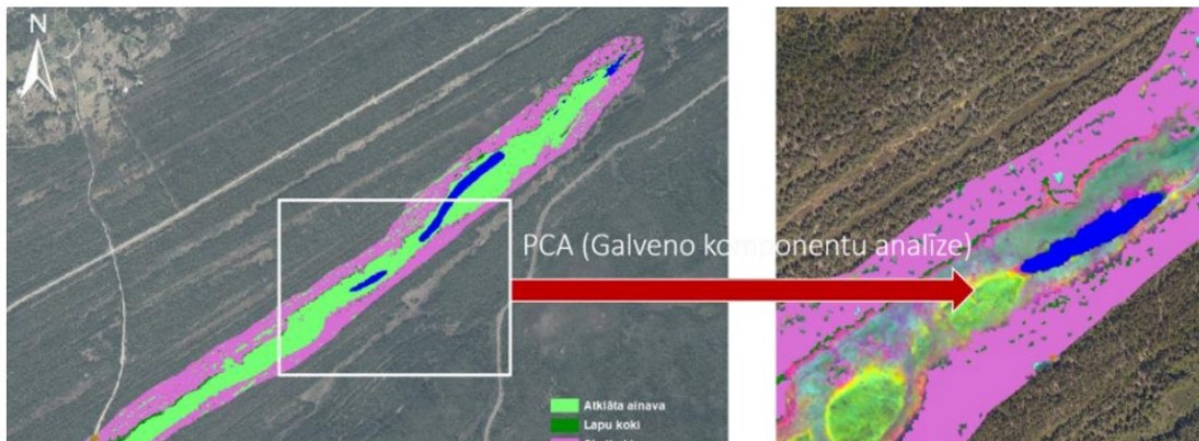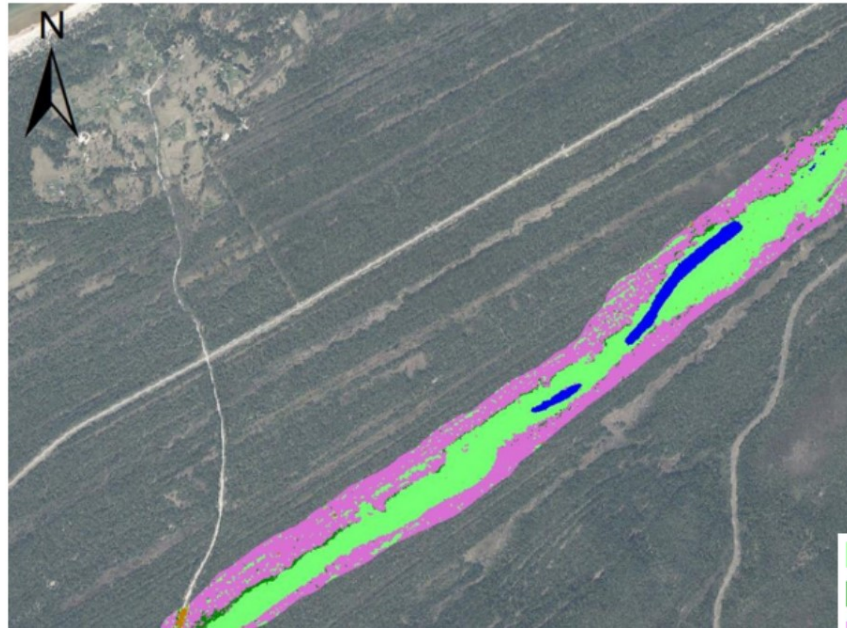
The open landscape hyperspectral data were processed using PCA and shown in the figure of three most informative components:

- ❑ main natural surface group classification;
- ❑ the surface group classification information integrated into areal map.

Dominant vegetation units were surveyed in nature. According to survey, GEST field protocol was completed for each class , marking the occupied boundary of each of the GEST type.

Maps from Sliteres National park analysed according to GEST methodology, using remote sensing data processing tools and surveying data:

- vegetation classification;
- GEST map.
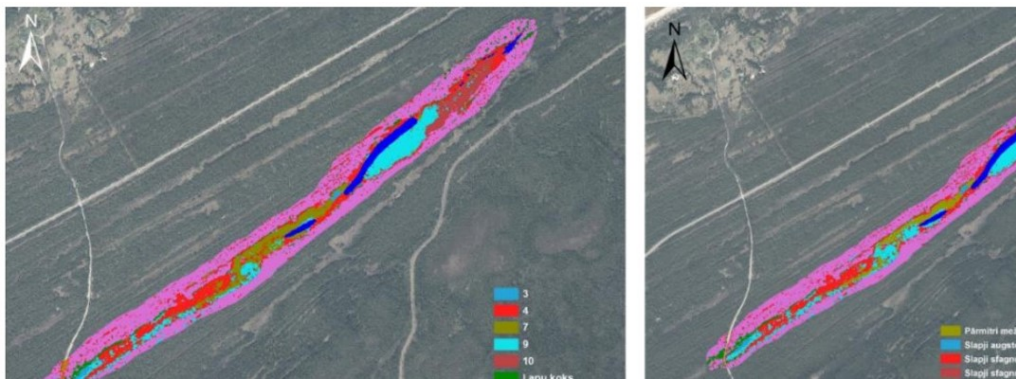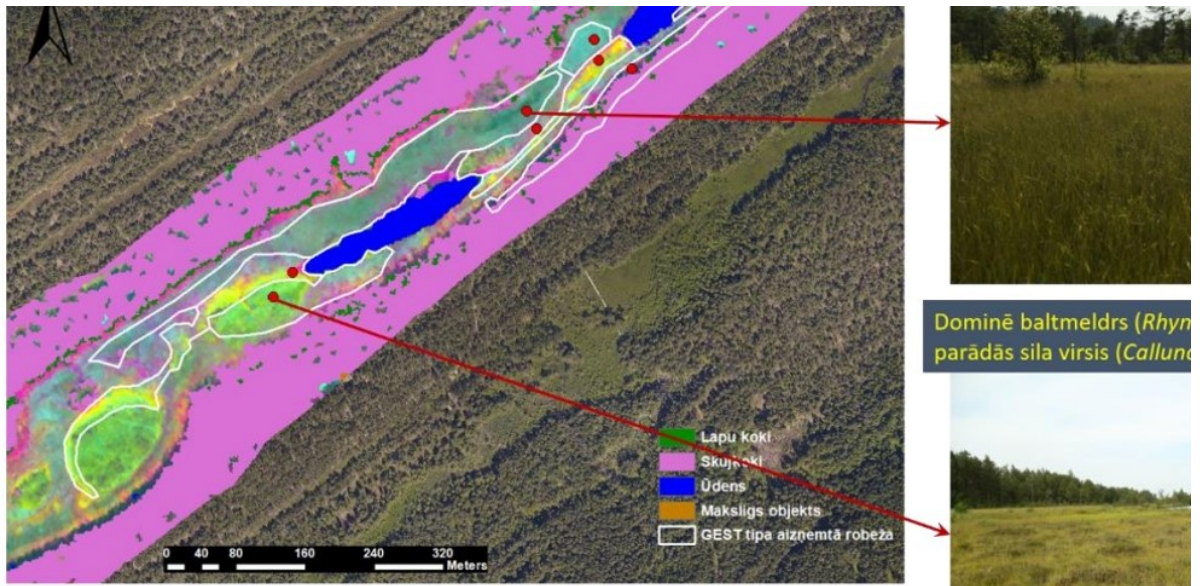
Each class of vegetation has specific values for greenhouse gases emissions. Therefore it is possible to evaluate the performance of the ecosystem regarding emission absorbtion and to model various future scenarios.

- Top right: CO2;
- top left: CH4
- bottom: global warming potential.
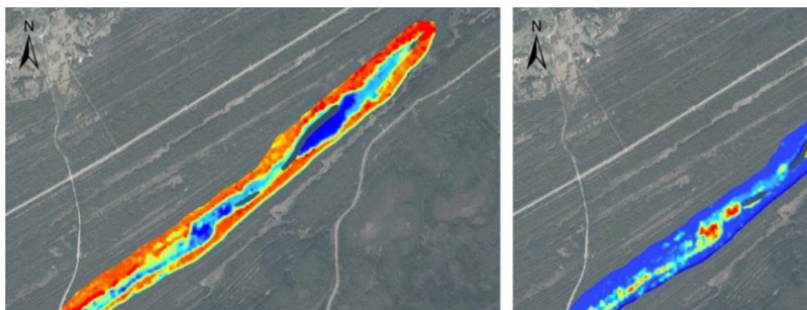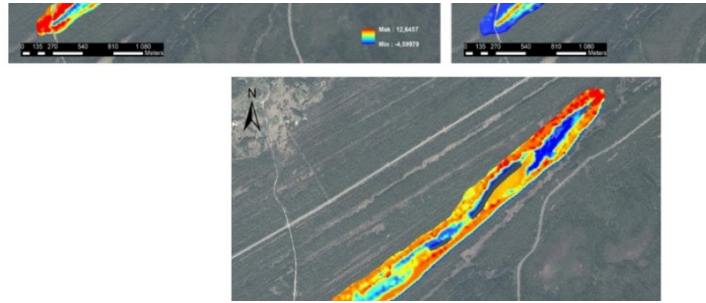
Tree felling was performed to improve the biotope of the wetland. Remote sensing allows examining the changes in the climatic ecology performance:

❑ CO2 before tree felling;
❑ CO2 after tree felling.
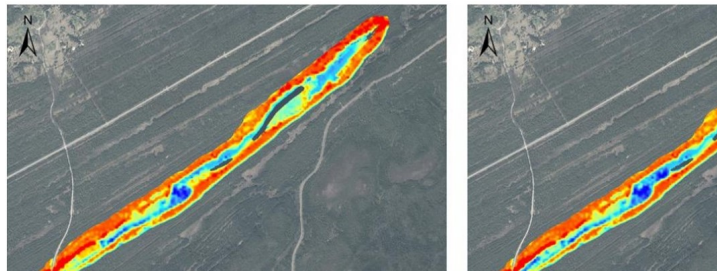
Tree felling was performed to improve the biotope of the wetland. Remote sensing allows examining the changes in the climatic ecology performance:

❑ CH4 before tree felling;
❑ CH4 after tree felling.
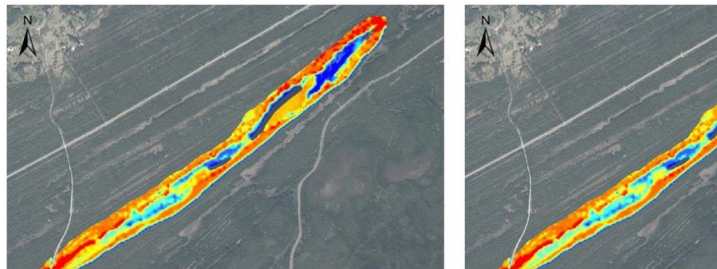
Global warming potential (GWP) is the sum of carbon dioxide and methan. According to the data, tree felling has positively influenced the environment:

❑ GWP before tree felling;
❑ GWP after tree felling.

Biotope restoration: 3D model of Madiešēnu wetland – solution

The project ought to restore a degraded habitat of the *Madiešēnu* wetland: the airborne research group obtained a 3D model and a hydrological modelling was made to improve the conservation of the ecosystem.
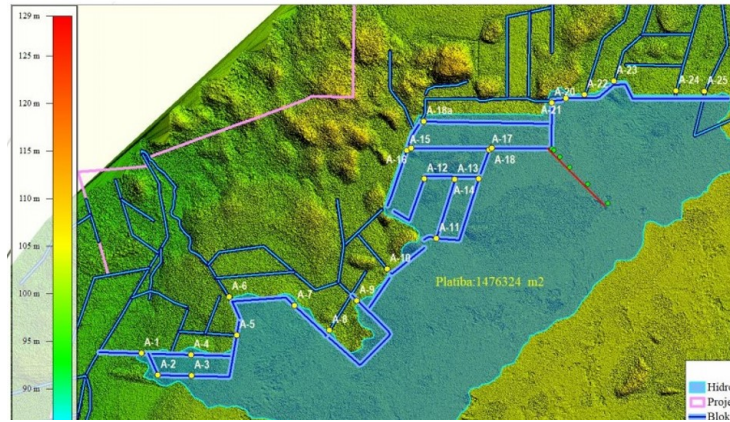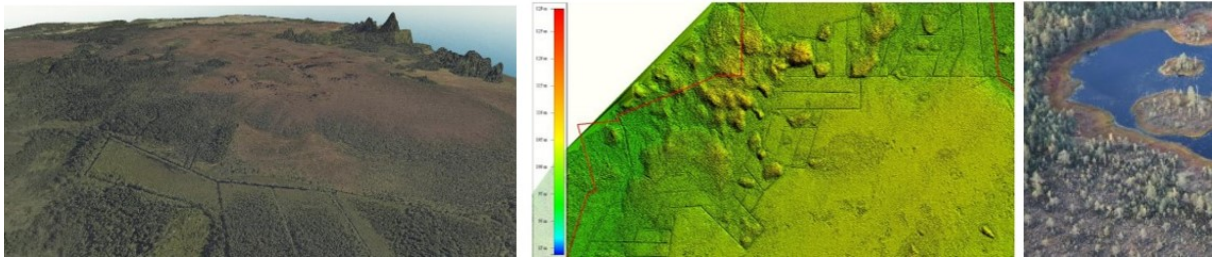
Biotope restoration of Corncrake habitats

The Corncrake (*Crex crex*) is a specially protected species, which has been breeding in *Dviete* wetland as in one of their most favorable homes. The alteration of the hydrological regime in the 20th century has caused the degradation of Corncrake's natural habitat.

Remote sensing - airborne hyperspectral and laser scanning (LiDAR) data – provided the possibility to model and assess corncrake habitats' territories.
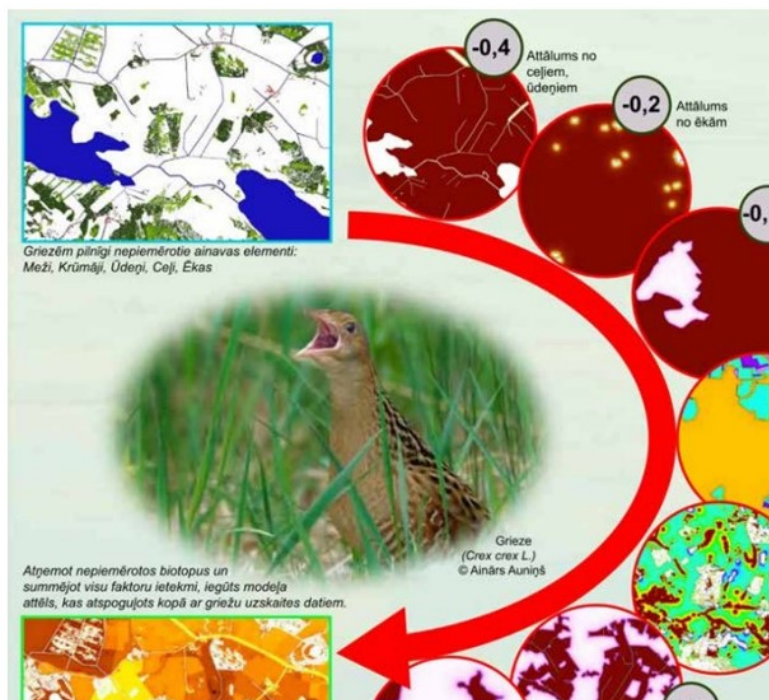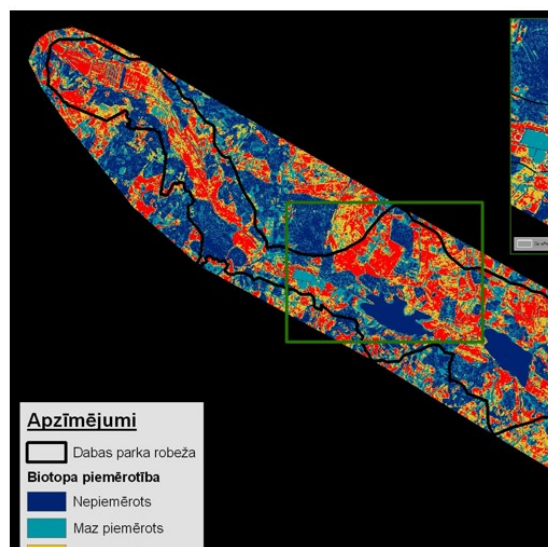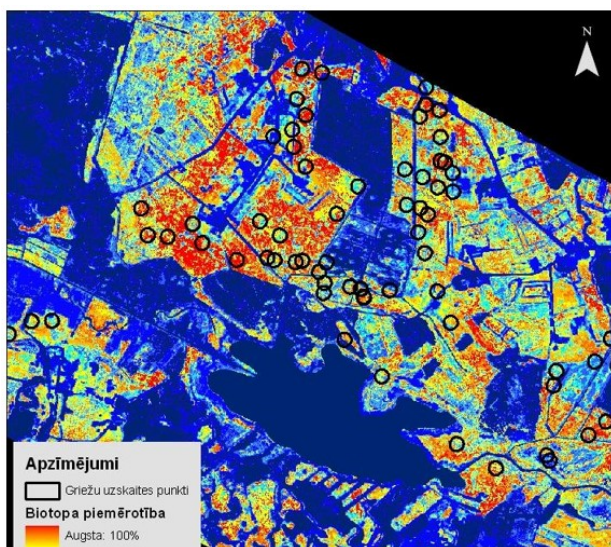
Biotope restoration of Corncrake habitats [24]

[24]

❑ Abaja, R., Fiļipovs, J., Strazdiņa, L. and Pakalne, M., 2019. Attālajā Izpētē Balstīta Siltumnīcefekta Gāzu Novērtēšanas Metodika Purviem. [pdf] Rīga: Vides Risinājumu Institūts. Available at: <http://www.videsinstituts. lv/assets/upload/userfiles/files/ Siltumn%C4%ABcefekta%20g%C4%81zu%20nov%C4%93rt%C4%93%C5%A1anas%20metodika%20purvos_GEST_VRI_2019.pdf>.

❑ Abaja, R., 2015. Upju palieņu atjaunošana un apsaimniekošana: life+ projekta dviete pieredze. [pdf] Rīga: Latvijas Dabas Fonds. Available at: <http://www.dvietespaliene.lv/images/publikacijas/low_ldf_publikacija_lv_10.11.16.pdf>.

❑ Institute for Environmental Solutions (2015.). Airborne Remote Sensing of Institute for Environmental Solutions. https://www. slideshare.net/Institute-for-Environmental-Solutions/institute-for-environmental-solutions>.

❑ Ķuze, I., 2012. Mitrāji Dabai Un Cilvēkiem. [pdf] Rīga: Dabas aizsardzības pārvalde. Available at: <https://hydroplan .daba.gov.lv/upload/File/Buklets_Hydroplan_LIFE.pdf>.

❑ Pakalne, M., 2019. Siltumnīcefekta Gāzu Mērījumu Nozīme Purva Ekosistēmās Un LIFE "Peat Restore" Projektā. [pdf] Rīga: Latvijas Universitāte. Available at: http://videsinstituts.lv/assets/upload/userfiles/files /Māra%20Pakalne _SEG%20mērījumu %20nozīme%20purva%20ekosistēmās%20un%20LIFE%20Peat%20Restore%20projektā.pdf.

❑ Videsinstituts.lv. 2019. GHG Monitoring In Wetlands. [online] Available at: <http://www.videsinstituts.lv/en/projects/land/ghg-monitoring-in-wetlands>.

PART VI

Photogrammetry applied to video game production: a growing trend [25]

What is photogrammetry?

Photogrammetry is the process of authoring a digital asset using multiple photos of the original real-world object, whose application fields are:

❑ cultural heritage: recording historic sites for restoration and future studies;

❑ topographic mapping: surveying large-scale landscapes through the use of aerial photogrammetry;
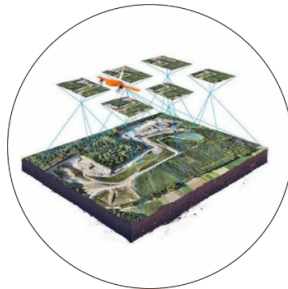
❑ engineering: reverse engineering of existing devices to obtain data about it, inspect and recreate;

❑ manufacturing: helpful for complex projects, where designing without an exact reference is non-viable

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[25]Excellent preliminary report written by Diana Trushina, Kristina Perkova (Russia), Veljko Vulanovic (Montenegro).

- ❑ and more …

Use in the gaming industry for objects, buildings and spaces

The Vanishing of Ethan Carter (The Astronauts 2014) is the first game made with the use of photogrammetry.
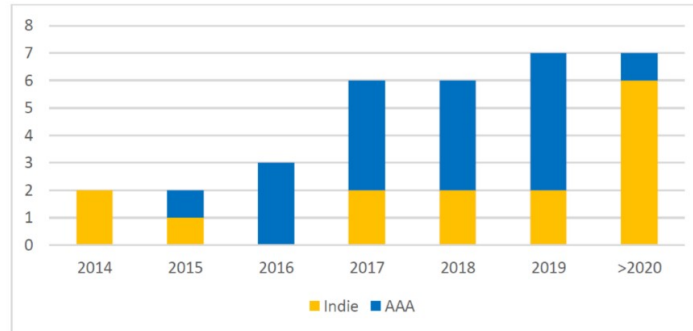
Published games per year featuring photo-scanned environment assets produced by companies

To capture famous roads and tracks, racing games use a combination of aerial photogrammetry, ground photogrammetry, laser scans and 360 video. When scanning extensive outdoor locations, other fields such as architecture, heritage and city planning tend to rely on aerial photogrammetry performed by UAV at a mid to high altitude.
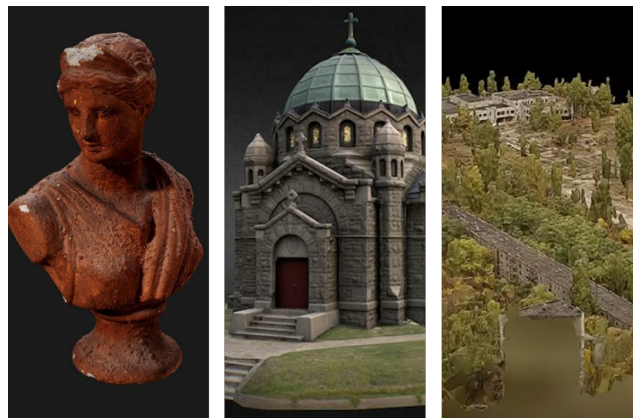
Equipment – An example of a general list of equipment to capture data for photogrammetry
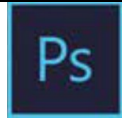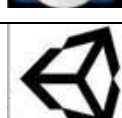
1- Camera: Canon 6D

2- Lens: Sigma 24-70 mm f/2.8 EX-DG HSM

3- CANON ring flash MR-14EX II with rechargeable batteries (2850 mAh)

4- Memory Card 256 Go (Class 10)

5- Laptop: Macbook Pro

6- Color checker passport photo (X-rite)

7- HOYA Polarizer filter PRO 1 DIGITAL 67 mm

8- Linear polarizer filter film

9- Secondary camera battery

10- Bag

11- Lenspen (Lens cleaner tools)

12- LASTOLITE Background support kit support H 3.52 x L 3m

13 - PHOCUSLINE Black background 3 m x 3 m

14- Lastolite Cubelite

15 - GODOX reflector 180 x 120 cm

16- Markers like tent pegs and chalk

17- GOPro

18- DJI drone Phantom 4 RTF

Software – An example of a general list of software to capture data for photogrammetry

	DCRaw: Convert RAW to TIFF		Knald: Baking textures
	Adobe Photoshop CC: White balancing, artefacts correction		Xnormal: Baking textures
	Reality Capture: Photogrammetry processing software		Substance designer: Baking textures
	3dsMax (or any related 3D software): Retopology, UV, LOD		VLC media player: Video to frames
	Instant Mesh: Retopology.		Substance painter: Manual tiling material.
	Unity Light Removal Tool: remove lighting from albedo baking.		Artomatix: automatic tiling material

Photogrammetry workflow: acquisition of a game asset

The workflow is divided in two major parts:

❑ capture;

❑ processing.

Capture	Calibration	Alignment	High mesh
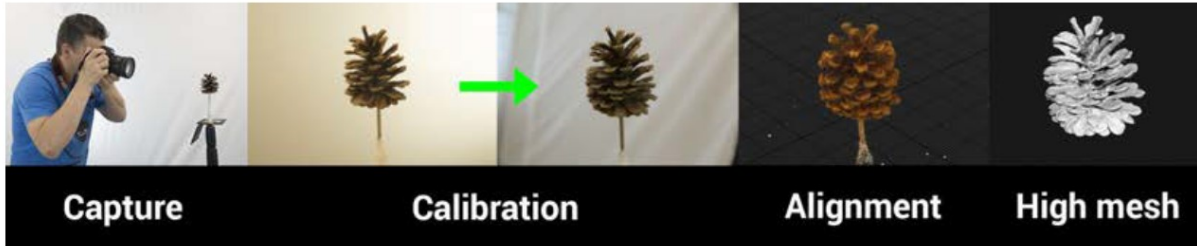
The first step is to gather multiple photos of the object from number

The photos need to be calibrated (white balanced)

The reconstruction application compares the shapes in the photos to generate a high resolution

Simplify	Retopology	UV Layout	Baking	De-lightin
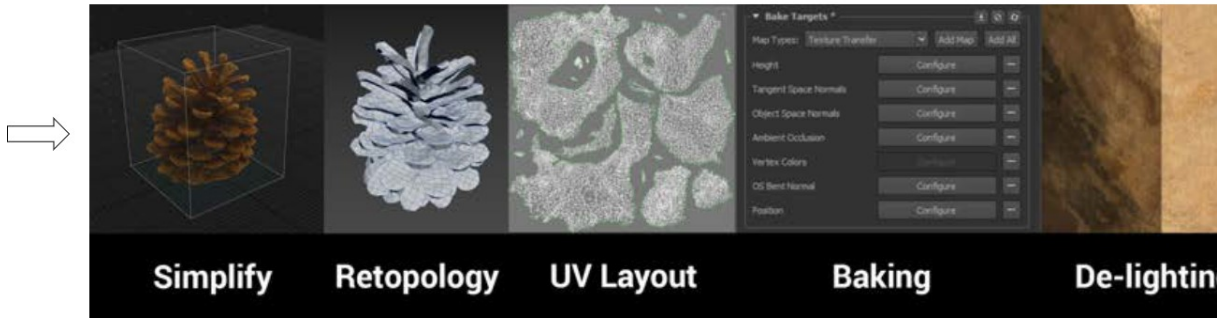
A low-resolution mesh for the baking process need to be created

A medium to low resolution mesh is exported from the reconstruction software and modified in a 3D software tool to be use as destination of the baking tools

Baking tools are then used to generate textures.

The textures need to light removed

How to capture a surface?

The photogrammetry process can be used to capture a surface that is then used in a game as a material.

Landscape surveying

Taking multiple photos from various angles

Taking multiple photos from vari
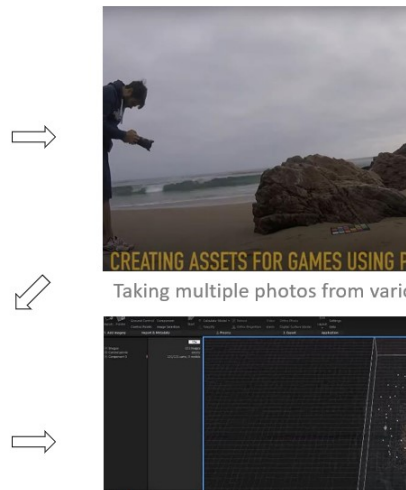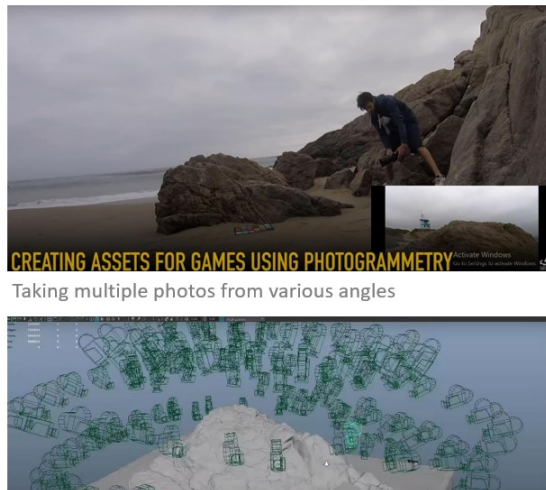
Preview mode
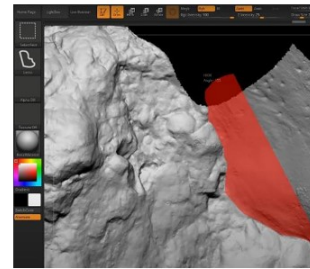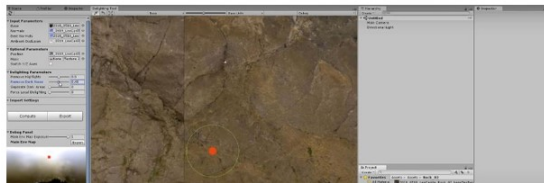
Cutting unnecessary geometry
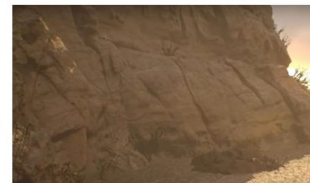
Prepare the area

First, find a location without shadows or use an occluder, to protect it from significant direct lighting, and remove the undesired elements.

At the location, use markers to define the area to capture. It is important to keep the same ratio between the real world and the virtual asset.

Scale metric

To keep the same ratio between real world and your reconstructed virtual assets, it is required to have a reference object of a known size in the reconstructed mesh that can be used to define the scale.

Any object can be used. The color checker is a good candidate as it is already located near the subject and includes a 5 cm ruler.

Shoot

To scan a ground surface, take top-view photos following a spiral path from the exterior to center. Move sideways with your head oriented toward the center.

Be sure to not interact with ground elements on the ground and pay attention to your body shadow and your own feet, otherwise the reconstruction will soffer from it.

An example result in Reality Capture: as expected, it is not possible to have a perfect path, you should just ensure that all of the area is covered.
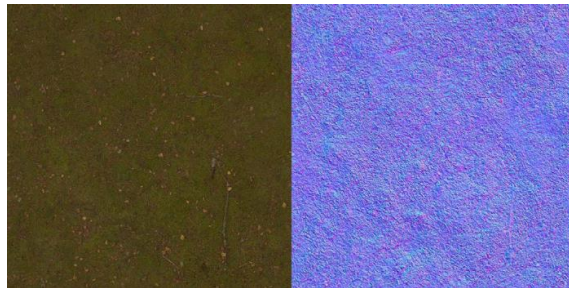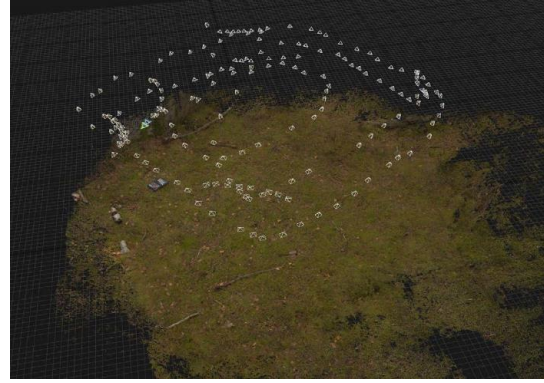
Resulting textures after full processing

Capturing a vertical surface

To scan a vertical surface, take pictures following a side-to-side path as shown in the example below. Place the color checker parallel to the surface if possible.
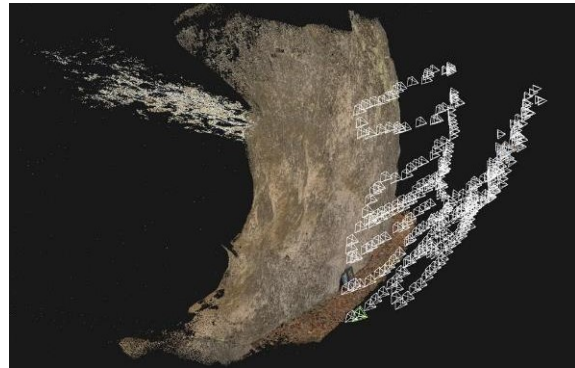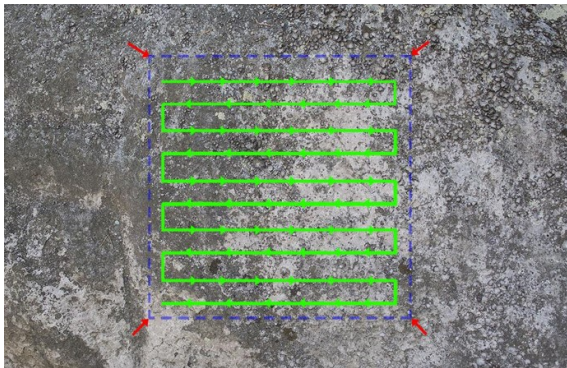
The capture can be done twice, the second time at closer position in order to provide more details to the material.

An example result in Reality Capture. As expected, it is not possible to have a perfect path, you should just ensure that all of the area is covered.

The reproduction of a surface is a good way to produce tileable materials.

These materials can then be used on handmade geometries or geometries reconstructed from a GoPro or a drone video.

Video in this case is a really fast way to author assets as it is really fast to capture without sacrificing the asset quality.
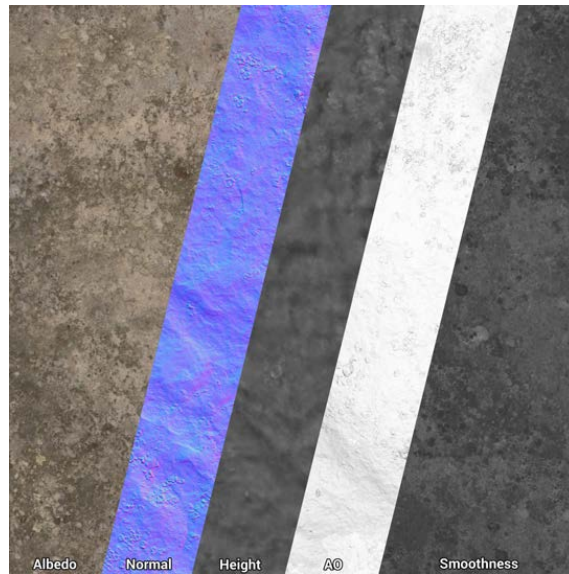
Detailed textures

Detail textures are a secondary layer of textures used in combination with the main texture to add detail at a different scale. The capture process for detail textures is the same as for regular surfaces, except that shots are focused more closely on a small area

The example shows on left the coarse subject, used to create the geometry and base material, and on the right. The detailed area scanned to produce detail textures.

Case study: "Chernobylite" by the farm 51

Science fiction survival horror game (in active development, release 2021) – Aim of project: recreate the exclusion zone in detail for the world to see.

The game's map was developed from 3D scans and recreations of the Chernobyl Exclusion Zone in Ukraine. Started as a simple "tour" program for Virtual Reality (Chernobyl VR Project), it developed into a full game based around the events that took place in the area.
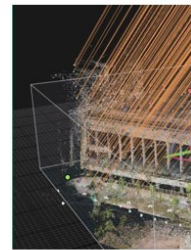
The Palace of Culture "Energetik" –

Drones used to capture the building from every

The building mo

Capturing environments
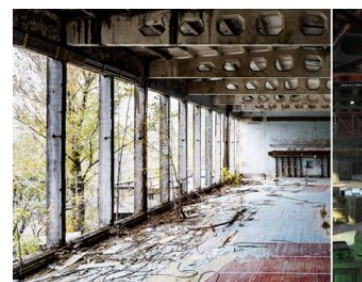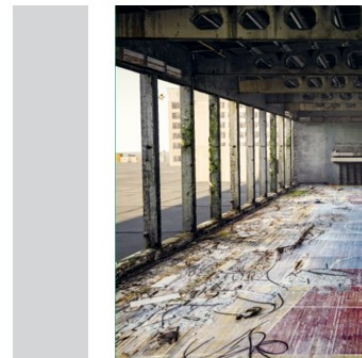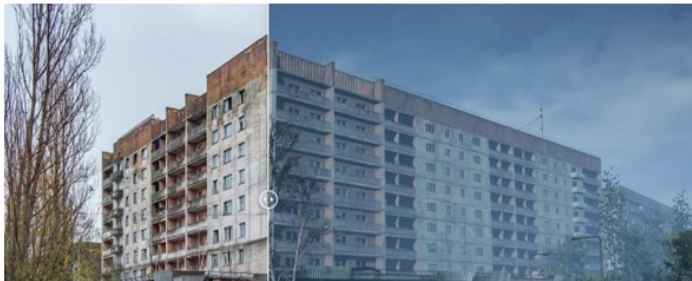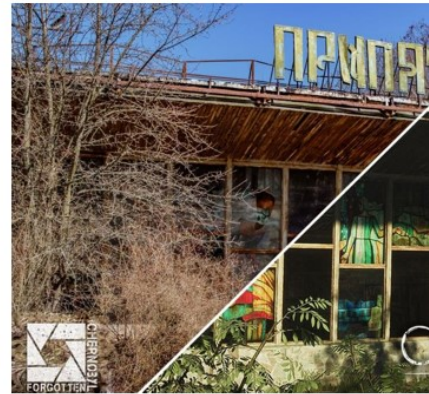
Capturing objects / "assets"

 "The Claw" is a large piece of crane machinery that was used in the weeks after the Chernobyl disaster.

When it was no longer useful, the Claw was removed from the crane and dumped deep in a forest where it was hoped nobody would find it.
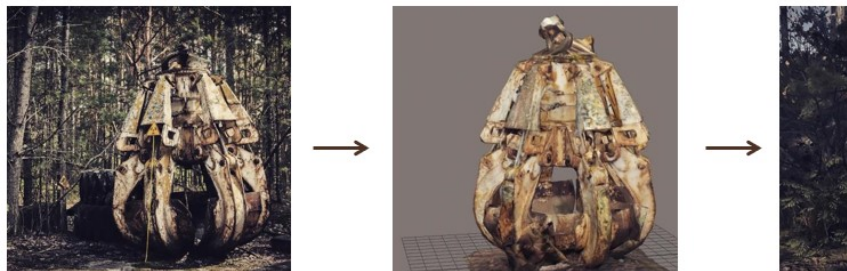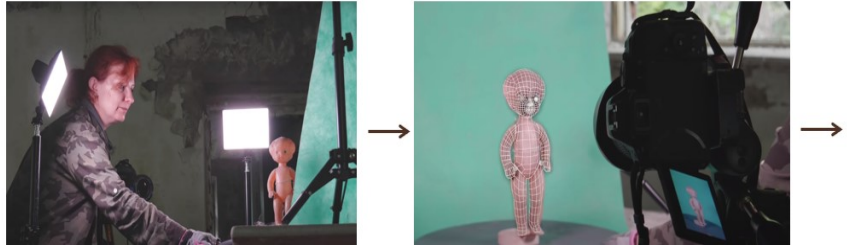
Various a

Portrayal of people

With the old asset creation, you get to a certain level of quality with a certain amount of effort and tech. Suddenly with photogrammetry your increase in quality is significant because of the tech and the techniques, not necessarily because of the effort. So when you're unable to use that technique for an asset that doesn't lend itself to photo-scanning, how do you bridge that gap? (Brown and Hamilton 2016, 24').

Behind it is a technology many are unfamiliar with, known as photogrammetry … So what is photogrammetry? In short, it's taking hundreds, perhaps thousands, of still images of a single object and feeding them into a piece of software, hitting a button, and having a 3D digital asset pop out. It's certainly not new technology, but it was never applied to gaming at scale until last year's The Vanishing of Ethan Carter (Hall 2015).

Photogrammetry is incredible … So much detail, so many intricacies, but most importantly, all of them just make deep sense. Cracks, stains, erosion – Mother Nature has worked a billion years on some of these assets, it's almost unfair to expect comparable quality from artists who spend no more than few days on similar assets (Poznanski 2014) [26].

Chernobyl disaster (April 26th, 1986)

[26]

❑   N.Statham, M.Fridenfalk, J.Jacob. November 2020. "Photogrammetry for Game Environments 2014-2019: What Happened Since The Vanishing of Ethan Carter". Conference Paper for "DiGRA '20 – Proceedings of the 2020 DiGRA International Conference: Play Everywhere"..https://www.researchgate.net/publication/345995149_Photogrammetry_for_Game_Environments_2014-2019_What_ Happened_Since_The_Vanishing_of_Ethan_Carter.
❑   S.Lachambre, S.Lagarde, C.Jover. June 23rd, 2017. "Unity Photogrammetry Workflow", Developer – Rendering Research.
❑   "Chernobylite" game official website: https://www.chernobylgame.com/.
❑   T.Collins, June 22, 2017. "A Look Into Photogrammetry and Video Games" https://medium.com/ @homicidalnacho/a-look-into-photogrammetry-and-video-games-71d602f51c31.
❑   D.Takanashi, May 30, 2019. "Call of Duty: Modern Warfare's photogrammetry captures gritty realism like never before" https://venturebeat.com/2019/05/30/call-of-duty-modern-warfares-photogrammetry-captures-gritty-realism-like-never-before/.
❑   "Chernobyl VR Project" official website: https://www.thefarm51.com/eng/projekt/chernobyl-vr-project-2/.

FAREWELL: Theory of Knowledge Diagrams

TABLE OF CONTENTS