Spatial Data Infrastructure for Urban Heritage Conservation in Afghanistan: The Case Study of Herat

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The development of "Spatial Data Infrastructure" (SDI) in the field of urban conservation in Afghanistan is a new and little explored topic. This article studies the framework of an SDI to provide a platform for sharing, assessing and discovering data by users and spatial data providers located in the public and private sectors. This paper not only contextualises these tools and methods in the old city of Herat, a city in western Afghanistan that contains important Timurid architecture, but it also describes the preparation phase and data management in the research project "Regeneration and Preservation of the Historic Urban Fabric of Herat." After archiving and managing various forms of spatial and non-spatial data related to the site, which have been produced by different institutions since 2001, the project develops an SDI by combining satellite images, spatial datasets and attribute data (e.g., social survey and household survey). It offers several conceptual models and also a geoportal to visualise, modify and discover the historic urban fabric of Herat. To reach this aim, the standards of ISO and OGC have been utilised. The product of this study enables key institutions in the field of heritage conservation to access the portal to obtain, modify and contribute data. Taking the strengths and limitations of SDI into consideration, especially in Afghanistan, this research aims to support researchers, urban planners and managers in proper decision-making and to protect Afghan heritage.

Keywords:
Spatial Data Infrastructure (SDI), GIS, Cultural Heritage, Spatial Analysis, Decision Making.

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INTRODUCTION

In Afghanistan it is difficult to gather data related to cultural heritage that can be used to manage and preserve historical sites. Since 2001, following the collapse of the Taliban regime in Afghanistan, various institutions, including governmental and non-governmental organisations and private companies, have produced different kinds of spatial data concerning places of historical value. At the same time, because of long-lasting armed conflict, the country has lacked institutions to manage data for documentation and conservation. In theory, such a process entails "interdisciplinary work where all the specialists involved in detailed investigations on an object of interest collect, interpret and share the data and the results of their interpretations [Rinaudo et al. 2007].

In June 2010, President Hamed Karzai (then-president of Afghanistan) issued a directive guideline relating to spatial data management. In article 2, paragraph 3, the Independent Department of Geodesy and Cartography was appointed to establish a spatial data infrastructure (SDI) among ministries and governmental and non-governmental institutions [GDCG 2010]. However, in the field of heritage preservation, to gather data individual organisations have spent millions of dollars and invested time and human resources. They usually have kept their data in private archives and seldom shared it with other organisations. After 2013, when the coalition led by the US started to leave Afghanistan, a substantial number of non-governmental organisations and private companies could no longer sustain their projects and also left the country. Two main questions arise in the wake of their departure:

a) What kind of data does each organisation have?

b) To what system could they transfer their data?

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Once the Afghan government understood the importance of digital data, they rushed to create databases. That encouraged many public institutions, including the government, to speed up accumulating data. This sudden interest also produced several challenges. First, multiple data centres have been established with the same objective but located at different institutions and using different formats, platforms and even different software. Second, this redundant work in the field has meant the loss of financial and human resources for the institutions involved and for the government, which suffers from a shortage of income. As a response to these challenges, a "spatial data infrastructure" (SDI) was developed to assist in the conservation of "Afghanistan's heritage" (AH). A GIS-enabled database, AH-SDI was deployed using the open-source solution GeoNode 2.8.

Heritage managers consider SDI an instrument for the inventory, documentation and management of knowledge concerning cultural heritage and as in many other fields they have accepted SDI as part of the natural advancement of more traditional databases. Furthermore, the underlying GIS technology is an efficient tool for storing, managing and analysing cultural heritage data. GIS technology has become widespread. It also offers appropriate 3D tools for cultural heritage visualization and mapping. Recent advances in GIS have included development of the proper instruments for both central and local authorities responsible for cultural heritage to build corporate information systems having this type of information technology as one of the essential infrastructure components [Petrescu 2007].

SPATIAL DATA INFRASTRUCTURE

Spatial data is significant in everyday decision-making and especially in economic, social and political decisions. Many of the goals and activities of organisations require access to convenient and integrated spatial data; this is especially the case with large-scale planning. Recognition of the importance of access to spatial data led to the development of SDI as platforms for empowerment in geo-information communities at various levels. SDI—internet-based technologies for the coordinated production, discovery, and use of geospatial information in the digital environment—have diffused worldwide in the last two decades [Budhathoki et al. 2008].

Rajabifard and colleagues [2004] state that an SDI *"will provide a base or structure of practices and relationships among data producers and users that facilitates data sharing and use."* They also describe an SDI as *"a set of activities and new ways of accessing, sharing and using geographic data that enables far more comprehensive analysis of data to help decision-makers chose the best courses of action"* [2004]. An SDI can make it much easier for different organisations to share data and resources. An SDI makes it possible to avoid redundant work, enhance the capabilities inherent in spatial information and increase the efficiency of investments and using the resources.

Viewing the core components of SDI as policy, access network, technical standards, people (including partnerships) and data, different categories can be formed based on the nature of interactions taking place within the SDI framework [Rajabifard et al. 2002]. In designing this structure, it is important to establish proper access methods and a framework for cooperation and collaboration among the organisations [Toomanian 2012]. Fig. 1 shows how managing data can affect people using SDI and vice versa.

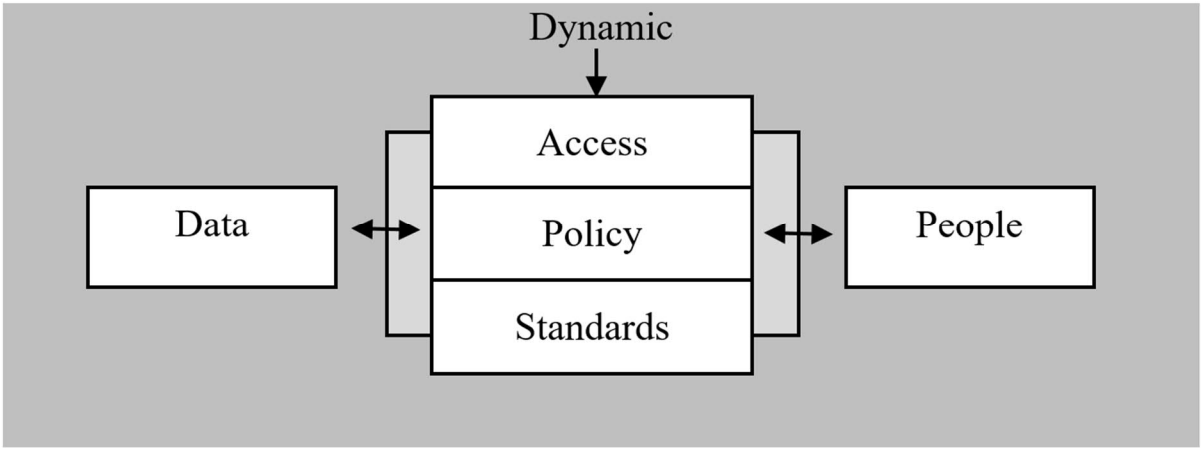

Fig. 1. Nature and relations between SDI components (adapted from Rajabifard et al. 2002)

MATERIALS AND METHODS

For managing heritage-related data, a suitable tool was required that could cope with the particular situation of Afghanistan, a post-war country with unreliable access to sites and with different types of data located in various places. The users also want user-friendly software that offers more than just a database and can be used for sharing data with internet-based space where data can be saved, edited, shared and worked with. The Afghan Ministry of Urban Development and Land proposed the idea of an "Afghan Heritage SDI" (AH-SDI). This is a software project, available to selected organisations through a geoportal, that is, *"a web application which acts as an access point to the shared Geographic Information [GI]"* [Xin et al. 2012]. According to Tait [2005] a geoportal can have four main functions including searching, mapping, publishing, and administration. To identify the tasks that need to be completed by participating organisations, as a first step, AH-SDI provided a list of GIS tools and basic data requirements. To collect this information, a desk study and interviews were carried out.

Herat was selected as a pioneer research project for three main reasons. First, the government of Afghanistan enlisted the city of Herat in the tentative list of World Heritage sites that has been compiled by UNESCO since 2004. The city is situated in western Afghanistan and is home to many historical monuments, including those *"from extensive development ordered by Queen Gawharshad during the 15th century AD, which resulted in a remarkable and unique ensemble of monuments in the Timurid style"* [UNESCO 2018a], among them the Mausoleum of Gawharshad and the Musala complex with minarets representing the peak of that style (see Fig. 2).

Second, local people in Herat pressured the central government to fulfil the demands of UNESCO for listing Herat as a World Heritage site. The AH-SDI project could satisfy some of the UNESCO demands, particularly those pertaining to heritage documentation and project preparation.

Finally, local people who are living in the historic urban fabric are suffering from lack of public facilities, including water, sanitation and electricity. To obtain those services they are willing to destroy their traditional houses and build new ones, which in many cases is illegal (see Fig. 3). Consequently, there is considerable interest in facilitating an appropriate culture-based regeneration of the urban fabric (see Fig. 3).

To enrich the AH-SDI and to gather reliable data, a variety of institutions were contacted. "Aga Khan Trust for Culture" (AKTC) was the first, because in recent decades they have been working in Herat. Besides their conservation work, they conducted a property survey between May 2005 and July 2006 [AKTC 2006] that provided the project with suitable metadata on the historic part of Herat.

Fig. 2. Part of Musala Complex including the minarets in Herat. (© R. Sharifi)

Fig. 3. Historic urban fabric of Herat. (© R. Sharifi)

With compiled baseline data, tools with necessary functions were designed in AH-SDI, these tools consisting of:

GIS tools

Tools for stakeholders are divided into eight categories. Each organisation requires some of these tools to work with GIS data (see Table 1).

Table 1. Types of tools users need

Type of data	Type of tools	Examples
Vector data	Basic	Zoom, pan, select, measure, search, create map, print, add data to vector layers, etc.
	Geoprocessing	Buffer, clip, intersect, union, merge vector layers, etc.
Attribute data	Attribute data	View, select, find, replace, modify, print, and delete tables
	Advanced attribute data	Create a graph, chart and report, statistical tools, etc.
Raster data	Satellite images	Zoom, pan, select, measure, create map, print and search
3D vector data	Basic 3D	View, zoom, pan, select, measure, search in 3d view, etc.
	3D analysis	Creating contour line, extrusion, rendering, elevation, etc.
	3D modelling	Fly through, export 3D model, animation, etc.

Basic data:

Users of AH-SDI, to work with this geoportal, need some essential information. A list of such primary or baseline data from our case study has been identified for the old city of Herat (see Table 2):

Table 2. Types of basic data users need

Items	Explanation	
Base Map	Providing geographical context for the objects shown on a *map* (e.g. Open Street Map, Google Map, Google Earth and so on).	
Basic feature data (For this part AKTC data centre)	Boundaries	Shapefiles of Afghanistan (provinces and state)
	Population	Residents and families
	Residential	Historic house, traditional house, modern house, ruin/open space
	Commercial	Market (modern), serai (traditional), shop, workshop, restaurant/ hotel
	Service / Public Building	Clinic, police station, cistern, governmental building, traditional bath, godown/storage, school/madresseh
	Religious	Mosque, shrine, takya khane (traditional mourning house)
	Drainage	Khandaq (traditional water channel)
Basic documents	Reports, charts, maps, surveys and pictures of Herat	
Basic satellite imagery	In the field of cultural heritage management, heritage practitioners can benefit a lot from satellite imagery. The latter can be used in survey, planning and implementations. Substantial data on our case study was received by us on Herat, from AKTC with a license for utilizing in AH-SDI.	
Basic aerial imagery	*Aerial* imagery is the taking of photographs from an aircraft or another flying object. It is high-resolution imagery and useful in urban management and cultural heritage. This image was received from AKTC with a license for use with AH-SDI	

Software architecture:

In developing the geoportal, the work was organised the way software development is organised. A small number of framework activities were identified to establish the foundation of our platform. For many software projects, framework activities are worked on iteratively, as a project progresses. That is, communication, planning, modelling, construction and deployment are applied repeatedly through many project iterations [Pressman 2010].

There are several ways to develop web applications, such as a geoportal, via an 'incremental process model' (see Fig. 4). Here, "the first increment is often a core product" [Pressman 2010]. The customer uses the product, and the next incremental model will be planned based on customer feedback, and the "process is repeated following the delivery of each increment until the complete product is produced" [Pressman 2010].

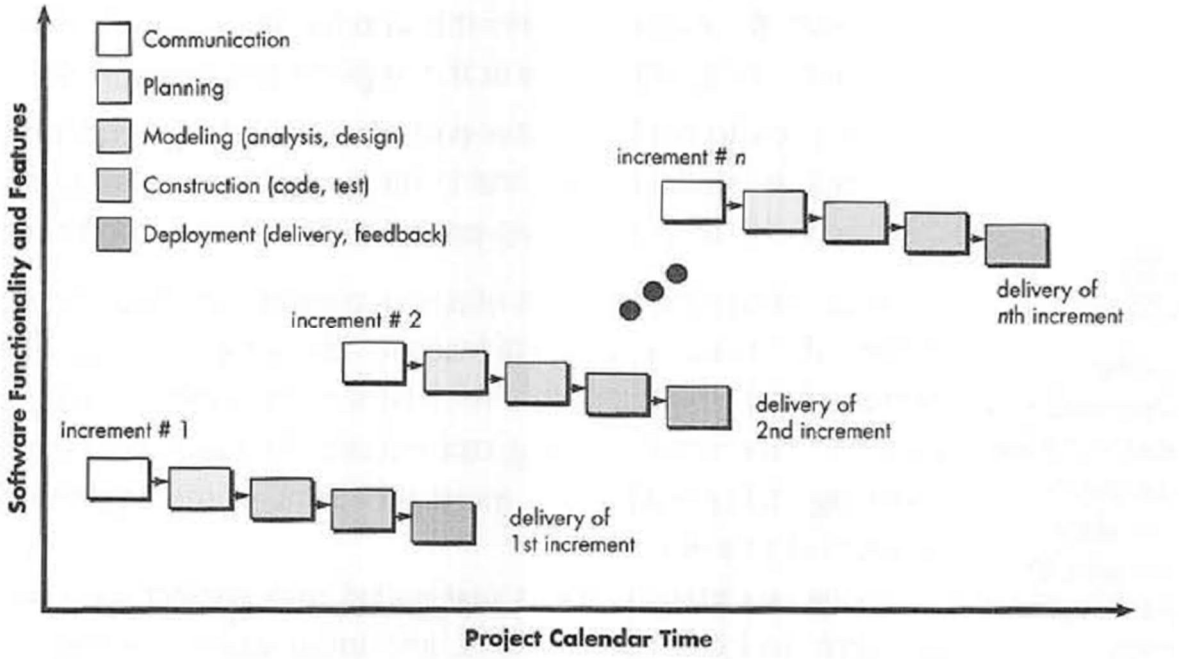

Fig. 4. Incremental Process Model (Pressman 2010)

Several types of spatial software can be used to implement a geoportal (see Fig. 5). They are either commercially or freely available. In this project, because of a lack of funding, the absence of legal support for such software in Afghanistan and limited access to required products and supporting offices that could help when problems arose with particular products, a free and open source online solution was chosen. Our experience was consistent with the conclusion that "*free and open source solutions support a wide range of industry standards that ease interoperability between SDI components"* [Steiniger and Hunter 2012].

The project has benefited from a number of services. The essential one is GeoNode 2. which is open source software for deploying an SDI and a web-based application and platform for developing "Geographical Information Systems" (GIS):

> *GeoNode core is based on Django web framework with few more dependencies necessary for the communication with the geospatial servers (GeoServer, pyCSW). GeoNode is configured to use PostgreSQL/PostGIS for its persistent store.* [Geonode 2019]

GeoServer, which is one of the main components of GeoNode, is open-source geodata middleware written in Java that allows users to share geospatial data and control access to geodata repositories. OpenLayers, a free mapping library, is integrated into GeoServer, making map generation quick and easy. "Web Map Service" (WMS) standard GeoServer also conforms to the "Web Feature Service" (WFS), "Web Coverage Service" (WCS), "Catalogue Service" (CSW), "Web Map Tile Service" (WMTS), and "Web Map Context" (WMC) standards [Geoserver 2019]. A map of Afghanistan appears in the GeoNode environment in Fig. 6.

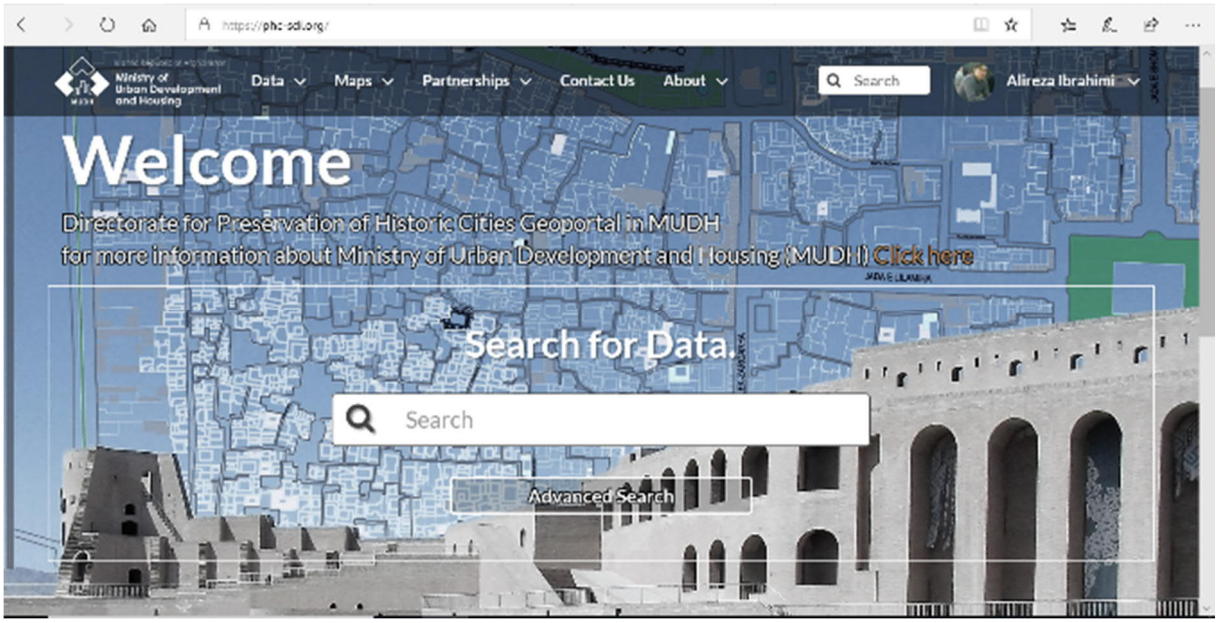

Fig. 5. AH-SDI Geoportal Homepage and login page

Data gathering:

To collect our data, beside the desk study, short-term fieldwork and interviews were conducted focused on select central institutions in the field of heritage preservation in Herat. The aim of the research was to figure out what type of baseline data these institutions require. It became evident that they need five primary data types (see Table 2), and eight tools (see Table 1). Table 3 shows the source data each institution needs.

Table 3. List of tools and primary data that organisations require

Name of the Institution	**Methods of Collecting Data**	**Demanded data**	**Tools**
Aga Khan Trust for Culture (AKTC)	Desk study	Base map Basic feature data Documents Satellite images Aerial images	Basic Tools Geoprocessing Attribute data Advanced attribute data Satellite Images Basic 3D 3D analysis
Turquoise Mountains Foundation (TM)	Interview	Base map Feature data Documents Satellite images Aerial images	Basic Tools Attribute data Satellite Images Basic 3D 3D analysis
Florence University-Italy	Interview and desk study	Base map Feature data Documents Satellite image Arial image	Basic Tools Geoprocessing Attribute data Advanced attribute data Satellite Image Basic 3D 3D analysing 3D modelling
Directorate of Historical city in MUDL	Interview	Base map Feature data Documents Satellite images Aerial images	Basic Tools Geoprocessing Attribute data Advanced attribute data Satellite Images Basic 3D 3D analysis 3D Modelling
Strategic Development Project (SDP) at the MUDL	Interview	Base map Feature data Documents Satellite Images	Basic Tools Geoprocessing Attribute data Satellite image Basic 3D 3D Modelling

Directorate of Survey and Study at MUDL	Interview	Base map Feature data Documents Satellite images	Basic Tools Geoprocessing Attribute data Advanced attribute data Satellite Images Basic 3D
Avicenna University-Kabul	Interview	Base map Feature data Documents Satellite images	Basic Tools Geoprocessing Attribute data Satellite Images Basic 3D 3D Modelling

RESULT AND IMPLEMENTATION

The AH-SDI project was accommodated within the "Directorate for Preservation of Historic Cities" (DPHC) at the "Ministry of Urban Development and Land" (MUDL). The former is a new department that, by presidential decree, was created within the structure of MUDL specifically for the conservation of historic cities in Afghanistan [Presidential Decree 2017]. AH-SDI is the first project of its kind in Afghanistan, dedicated to documentation and preservation of urban heritage all over the country. It allows users to upload GIS layers and documents and to define permissions for the viewing, editing and downloading of their data. Also, users can log in to the geoportal, search within GIS data and documents (Fig. 7), view data that other users have uploaded, and edit and create maps from data (Fig. 8). In terms of copyright and the ownership of data, several approaches have been identified in terms of limiting access to the uploaded data.

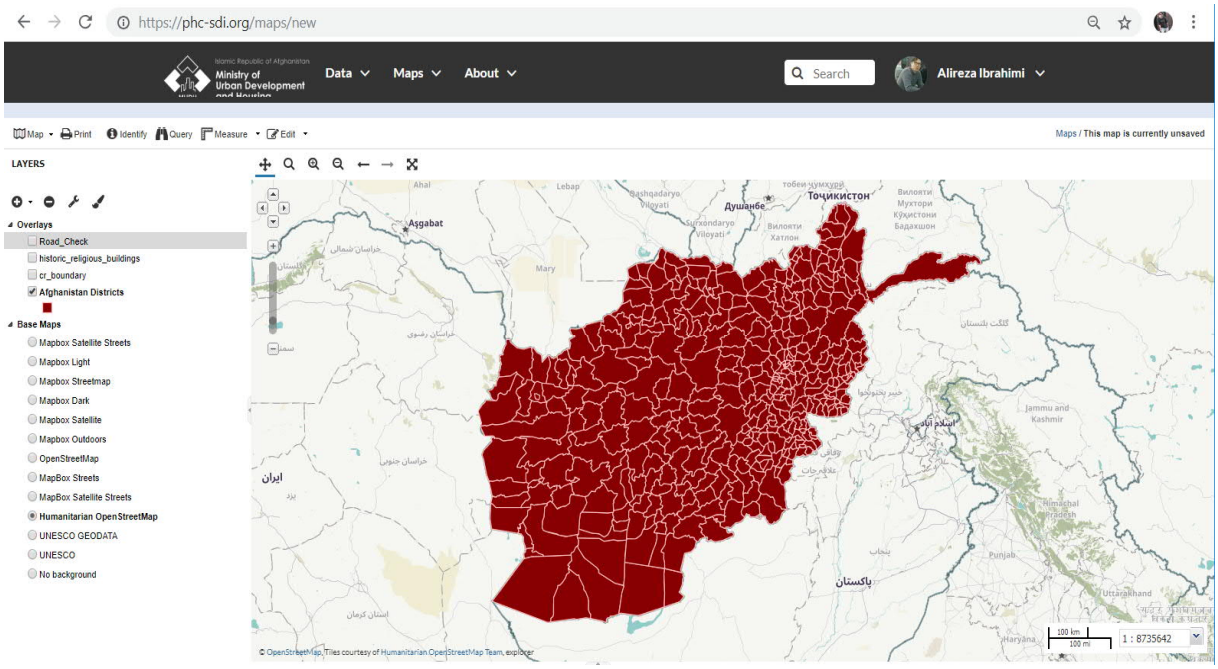

Fig. 6. Screenshot of layer preview with a base map

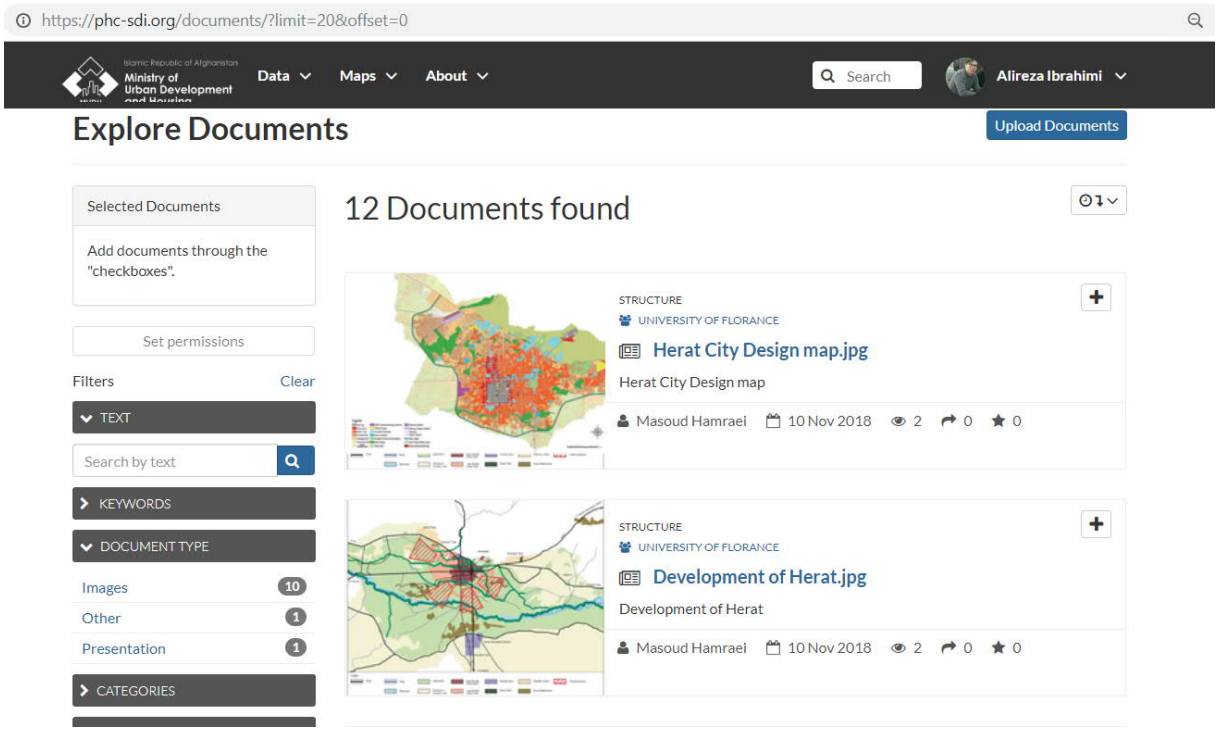

Fig. 7. Research documents about Herat in AH-SDI Geoportal

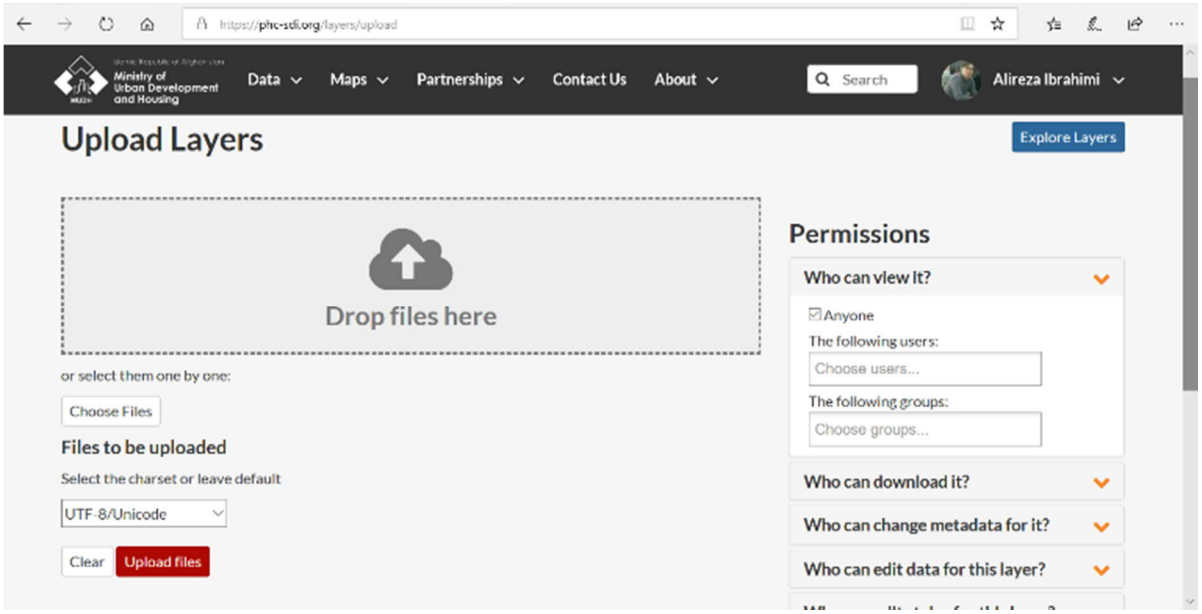

Fig. 8. Screenshot of Upload Layers page and permissions

Deployment:

To implement projects in a country like Afghanistan, with its insecurity and armed conflict, it is necessary to use a suitable approach. Two essential problems are a lack of proper infrastructure and a lack of specialised staff. DPHC had to change its data server three times, which included one instalment at the IT centre of MUDL, one commercial host in Spain, and, finally leading to a viable solution, an agreement of cooperation with the "German Archaeology Institute" (DAI) which allowed the project to use server hardware physically located in Berlin. The server problem affected the research work schedule, approach, and technique.

In the beginning, the project was established within the structure of MUDL. Therefore, the "IT Center" (ITC) Directorate was the first to deploy the data [ITC 2018]. There were distinct advantages at the ITC:

- The host and domain were free of charge, and there was no limitation to bandwidth and domain usage.
- Maintenance and management were easy because the server was physically close to the researchers and belonged to the ministry.

But at the same time there were some limitations:

- The necessary infrastructure in Kabul, such as electricity, was unreliable and sometimes caused server downtime, preventing users from getting access to the data.
- Afghanistan is still in a state of armed conflict, and political changes and institution transformations are rapid (since the start of the project in April 2018, the MUDL has experienced three ministers, and at the same time, two central institutions, the Land Administrations and the Ministry of Urban Development and Housing have been merged).
- The old structure of governmental ministries is too slow to cope with new technology, and they do not have much experience using the system.

To solve these problems, the server was changed from MUDL to a commercial host. The new host was acceptable in terms of speed and reliability and it provided backups and took over technical responsibility. But the host and domain were not free, and there was no viable process for payment by MUDL. Therefore, the fees were paid from personal accounts without the possibility of reimbursement. But the most important problem was that the partners who wanted to share data with the project did not trust a commercial host that was unknown to them.

In September 2018, after several negotiations, the DAI, a research institution which carries out archaeological excavations, expeditions and other archaeology-related work, was chosen as a technological project partner for DPHC [DAI 2018]. The advantages of this arrangement have been these:

- Host and domain are free for MUDL.
- Speed and reliability of the hosted site are good.
- Backups and other responsibilities are taken over by the DAI, in direct coordination with the AH-SDI project, until all such liabilities can be transferred to MUDL.

But there remain some limitations. The sustainability of the project in the frame of this cooperation remains the primary concern. The concern mainly stems from the context of Afghanistan, a country in which armed conflict has persisted for several decades. To address this challenge, having a third partner organisation can be an option. Such a partner should be able to take over long-term technical responsibility. DPHC is currently considering the UNESCO Kabul Office and Avicenna University in Kabul as the best candidates.

WIDE OPEN PROSPECT

The new government (National Unity Government since 2013) has been trying to centralise all digital information [GDCG 2010], providing a unique platform for cultural heritage managers to share data between stakeholders. By creating a new department dedicated to the historic urban fabric at the MUDL, the government has facilitated the documentation and registration of Afghan heritage. From a more global point of view, it is clear that IT has been expanding at high speed during the past decade, while Afghanistan has been beset by war. Therefore, the state has not been able to provide a platform for new technologies to enter the different fields of management. In the domain of IT, GIS-related software is among the most fertile areas to explore, and this SDI project can be a pioneer of its kind.

The biggest challenge regarding the implementation of the AH-SDI project concerns the sustainability and maintenance of this new data center, as was mentioned in the description of our negotiations with the DAI. Some international documents have emphasised this topic, such as the UNESCO Oman Recommendation that suggests *"that all the technical information produced by experts, agencies and UNESCO be centralised and shared as a single system by the Government of Afghanistan"* [UNESCO 2018]. A credible strategy needs to be formulated with the coordination of national and international organisations to allow the new data centre to become a stable component of Afghanistan's new digital infrastructure. It is vital that the Afghan authorities establish inter-ministries cooperation that can support its updating and maintenance.

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