INTEGRATED DEPRIVATION AREA MAPPING SYSTEM FOR DISPLACEMENT DURABLE SOLUTIONS AND SOCIO-ECONOMIC RECONSTRUCTION, SUDAN

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Abstract

African great metropolises are rapidly growing due to rural-urban migration. In Khartoum, Sudan, the urban population increased from around 245,000 in 1956, to over 8 million, due to wider changes in urbanization patterns driven by climate change, civil-unrest and protracted forced displacement. With the lack of sustainable planning strategies to secure land tenure and access to services, the level of deprivation in Khartoum informal settings witnessed a swift increase in urban poverty, that requires mapping the vulnerabilities of the urban poor and providing evidence-based data to support displacement 'durable solutions'. In response, IDeaMapSudan was launched in 2020, as a joint collaboration between Sudan Urban Development Think-Tank, Ministries of Social Development, Physical Planning, Infrastructure and Transport, and the Faculty Geo-Information and Earth Observation Science (ITC) at Twente University, to achieve three key objectives: 1) Provide capacity-building on using Earth Observation (EO) and spatial data innovation to fill the gaps in existing administrative GIS maps, 2) Develop a community-led geo-spatial database for mapping deprived areas (e.g. informal settlements) using socio-economic indicators for deprived areas in Khartoum, 3) Establish an 'Integrated Deprivation Area Mapping System' for data sharing and communication, that can guide the city planning decision -making process. Using Expert discussions and local field data collection, IDeaMapSudan revealed that local data on deprivation do not exist or are scattered within different local authorities, and the need to overcome the challenges of urban governance and technical congruence between EO data and community-driven vulnerability assessments is essential, by having a spatial distinction between slums, informal settlements, precarious areas, and other deprived areas, beyond the limited understanding of physical deprivation and humanitarian led vulnerability assessments.

Keywords: Deprivation, Earth Observation, Geospatial Information, Informal Settlements, Urban Poverty.

INTRODUCTION

Urban poverty in Sudan

According to the African Development Bank, 25% of Sudan's population falls below the extreme poverty line (ADB, 2018). The definition of poverty is the "lack" or "deficiency" of the necessities required for human survival and welfare (Wratten, 1995). Urban poverty is associated with urbanization drivers that shape economic and social exclusion patterns, access to public services, income and employment opportunities. Witnessing decades of conflict, instability, climate change vulnerabilities, weak urban governance, rural urban migration and internal displacement, the situation of urban poverty is exacerbating in Sudan. There have been several attempts by government agencies, NGOs, donors and international organizations to measure urban poverty with the aim to tackle its key drivers. Nevertheless, with the lack of evidence-based data on vulnerability levels, the challenges towards the implementation of effective pro-poor policies will continue to hamper actions towards inclusive urban development in Sudan. Poverty, and in particular urban poverty, is a complex concept and should not be reduced to only income poverty (e.g., as expressed by the poverty line). Threshold values such as $1.9 per day provide a general impression about income poverty, but are limited due to difficulties in setting suitable thresholds and in particular access to reliable income data (Kakwani & Son, 2016). Furthermore, deprivation experienced by individuals, households and communities is more complex than such a simple income measure.

The concept of deprivation understands poverty as a multi-dimensional phenomenon (Abascal Rothwell, Shonowo, Thomson, Elias, Elsey, Yeboah & Kuffer, 2021). For example, households might be deprived in terms of durable housing material or access to basic services (e.g., water). Communities might be deprived in terms of infrastructure or availability of open spaces. Deprivation-related data are routinely collected in some High-Income Countries (HICs). For example, the UK has a long-standing tradition of producing deprivation indices (McLennan et al., 2019) such as the index of multiple deprivation (Figure 1). However, Lower Middle-Income Countries (LMICs) do not have easy access to data nor do they have the capacity to collect and process data that would reveal the complex geographic patterns of multiple deprivation. Existing data on LMICs that relate to aspects of deprivation often have consistency and accessibility issues. For example, data are collected for some areas but are not available at city scale and/or data are stored in a way that they cannot be accessed. Furthermore, local stakeholders often do not have the capacity to work efficiently with the rapidly growing amount of open data and innovations in Free and Open-Source Software (FOSS). Open data combined with FOSS could be a solution to overcome the bottleneck for LMICs, but capacity development is required to utilize such new and constantly evolving sources.

Overview of IDeAMapSudan

The IDeAMapSudan Project stands for (Integrated Deprivation Area Mapping System for Displacement Durable Solutions and Socio-Economic Reconstruction, Sudan). It was launched in Sept 2020 through a consortium led by the Faculty of Geo-Information Science and Earth Observation of the University of Twente (UT)-Netherland in partnership with Sudan Urban Development (Think-Tank) Organization (SUDTT)-Sudan, African Population & Health Research Centre (APHRC)-Kenya, and Université Libre de Bruxelles (ULB)-Belgium. Launched mid-2017, it aims to build the capacity of local entities, especially government bodies, to create and use an integrated system for mapping deprived areas. As such, a collaboration was established with the ministries of: Social Development, Urban Development & Roads and Bridges, Transport, and Physical Planning (Khartoum State) to implement the project.

Measuring Urban Poverty

There are different indicators established to measure poverty, locally and internationally, however the integration of data and its representation in geographical form to reflect poverty and the levels of deprivation in Khartoum is lacking (Eltayeb, 2003). The lack of spatial data creation and collection, data management & analysis, and the ability to translate spatial data into relevant policy is the major drive for the IDeAMapSudan Project. Therefore, the aim of IDeAMapSudan is to develop a community-led geo-spatial database for mapping deprived areas (e.g. informal settlements) by linking the geospatial data with community-based data, in collaboration with local governments and civil society organizations. That will help in understanding the displacement and urban poverty challenges and opportunities and support decision making for sustainable socio-economic reconstruction in Sudan. The project consists of four main phases as follow:

1) *Gap analysis and basic spatial analysis:* Mapping local key stakeholders including government and non-government entities, and working in collaboration to identify data gaps and potentials of EO for urban development in Sudan.
2) *Technical training of trainers (ToT):* a team of young professionals was selected from two Ministries in Sudan to gain advanced technical knowledge on GIS and EO including community-based data collection. The ToT team is trained to lead the creation of IDeAMapSudan System and building the deprivation model. Through working with communities and local NGOs the system is tested in two pilot areas in Khartoum state.
3) *Working with IDeAMapSudan:* the team will work on transferring the knowledge through conducting training workshops for local communities, government and NGOs.
4) *City-to-City (C2C) political knowledge exchange:* to discuss and stimulate the regional scaling of IDeAMap in the region.

RELATED STUDIES

Data to map the Geography of Poverty

Data is key for development; yet up-to-date, actionable data is often missing (The World Bank, 2021). For example, official population counts in informal areas differ greatly in distinct sources of official estimates (Thomson et al., 2021). Crowd-sourced information, such as Open Street Map (OSM), can supplement that, but they do not have a homogeneous quality (Herfort et al, 2021). Earth Observation (EO) can help fill this knowledge gap. There has been a significant increase in the amount of satellite imagery available to the public over the past decades (Kavvada Metternicht, G., Kerblat, F., Mudau, N., Haldorson, M., Laldaparsad, S., . . . Chuvieco et al., 2020). Such imagery enables comparing urban areas over time, by comparing current imagery with historical satellite imagery, and also space as the urban form in one city or neighborhood can be compared with another (Taubenböck, Esch, Felbier, Wiesner, Roth & Dech, 2012). Indeed, EO has shown much potential for mapping urbanization patterns and deprived areas (Kuffer, Pfeffer, and Sliuzas, 2016). Very-high-resolution, commercial imagery enables the identification of buildings and building typologies (Kuffer *et al*, 2016) and drones can help develop detailed plans for urban upgrading projects (Gevaert, Sliuzas, Persello, & Vosselman, 2018). Other types of satellite sensors can collect supplementary information. For example, radar satellites can pass through the clouds and capture the extent of flood events (e.g., UNOSAT, 2020) and night-light imagery can give a hint to the economic productivity of certain neighbourhoods (Bennett & Smith, 2017). Perhaps the greatest limitation of EO data is that it can only directly capture physical information – about the structure of buildings – and can model socio-economic conditions but it does not directly measure the latter. This is why it is extremely important to match the observations from space with community-based socio-economic information and an understanding of the local context.

Overview of IDeAMap: A conceptual modelling framework

To support routine and accurate mapping and characterising of deprived urban areas, the IDeAMap network developed the Domain of Deprivation Framework to identify relevant geospatial and EO data (Abascal *et al*., 2021). This framework builds on existing deprivation frameworks (e.g., the IMP 2019). Such frameworks avoid modelling deprivation as a binary phenomenon, but as a continuous layer. Existing deprivation mapping frameworks typically use census data. However, in many LMICs such data do not exist or are dated (e.g., the last census in Sudan took place in 2008). Such dated data do not reflect the present physical and socio-economic conditions. In particular in fast-growing and transforming LMIC cities such data are rapidly outdated also with regular censuses (i.e., commonly every 10 years). The Domains of Deprivation Framework (Figure 1) groups locally meaningful indicators into 9 domains at 3 scales. Two domains reflect deprivation measured within households. Four domains reflect area-level deprivations (social hazards & assets, physical hazards & assets, unplanned urbanisation, and contamination). Three domains reflect aspects of deprivation that relate to the connectivity to the city (i.e., infrastructure, facilities & services, and governance). A guide for authorities (Thomson *et al*., 2021) provides guidance for the operationalisation of all domains with openly available geospatial data (e.g., night-time lights, air pollution) and contextual image features (e.g., Sentinel-2 satellite imagery).

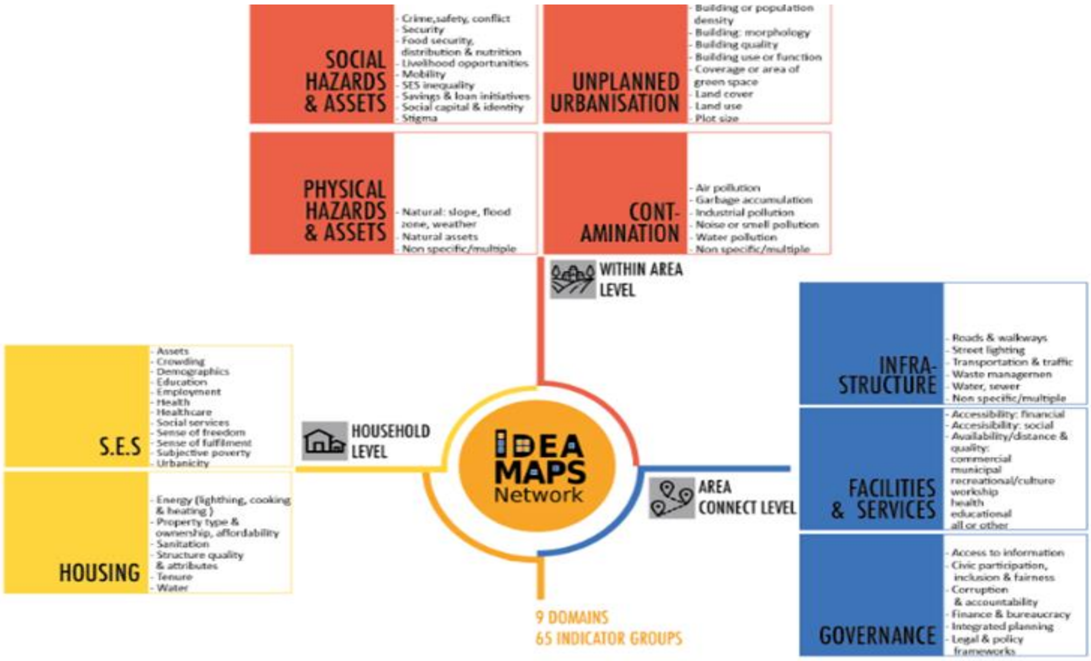

Figure 1: *IDeAMap Domains of Deprivation Framework (Abascal et al., 2021).*

METHODOLOGY

The methodology provides an overview of the efforts to co-design a deprived area mapping system for Khartoum that leverages the strengths of EO data, open data and FOSS combined with training the capacity of local key actors to develop and use such a system. IDeAMapSudan aims to overcome data availability gaps on deprived areas and focuses on low-cost and sustainable solutions. Parallelly, the capacity of local stakeholders (technical and non-technical) will be built by using EO and spatial data innovations.

Introduction to Study Area

The total population of Khartoum State according to the last census in 2008 is 5.274 million people, who is almost 14% of the total population of Sudan. This makes Khartoum the largest state in terms of its number of populations compared to the other states of the country (Central Bureau of Statistics, 2009). Based on the 2.4% annual growth rate, its population projection is estimated at 6.793 million in 2020. The proportion of the urban population of Sudan has been continuously increasing since the first census in 1956 when it was recorded as 8.8% compared to 29.8% in the 2008 census where 80% of Khartoum's population were classified as urban (National Council for Physical Development/UN-HABITAT, 2014).

Greater Khartoum, within Khartoum State, comprises three cities: Khartoum, Omdurman, and Khartoum North (Bahri), separated by the Blue and White Nile rivers. Several development plans were developed for Greater Khartoum responding to the rapid growth of the city, however most of the plans failed to be fully implemented and its capacity to address the needs of vulnerable groups and urban poverty issues is questioned. Not only the lack of financial resources hindered the implementation of those plans, but also due to land issues and the lack of coordination and conflict between the different governmental institutions (Pantuliano, Assal, Elnaiem, McElhinney, Schwab, Elzein, & Ali, 2011). Demolition of illegal settlements (squatters), relocation to new sites, re-planning of informal settlements to be incorporated within the urban context, and up-grading of some areas were major policies undertaken by the Government to address the informal expansion of Khartoum (Three City Land Nexus Research Team, 2020). As mentioned before, IDPs and poor migrants have settled in different areas around the city. Ahmed & EL-Battani (1995) identified three categories of the poor in Khartoum; 1) Urban poor, people with low levels of education and semi-skilled workers, 2) IDPs, who were forced to leave their places seeking better living conditions in Khartoum, 3) the so called "New Poor" who became poor as a result of liberalization policies to lower wages and remove subsidies. A more recent study in 2009 led by UN-HABITAT considered 60% of Khartoum's population as urban poor and were classified based on their locations (Table 1) (Murillo, et al., 2009).

	IDP camps	Squatter areas	Villages	Low-income neighborhoods	
				High middle density (including renting)	Low density (sites and services)
Estimated area	18 km² 1,800 hectares	15 km² 1,500 hectares	38 km² 3,800 hectares	12 km² 1,200 hectares	94.5 km² 9,450 hectares
Estimated population	400,000	400,000	700,000	700,000	2,100,000
Density inhabitant-hectare	222	266	184	583	100
Percent of total population	5	5	10	10	30
Percent of urban population	10	10	15	15	50

Table 1: *Categories of Urban Poor by location (Murillo, et al., 2009).*

The continuous growth of Khartoum's population and its expansion versus the absence of adequate development plans has put more burden on its residents, especially the poor urban communities. In addition to their low level of income (monetary poverty), they are also suffering from non-monetary poverty by lacking adequate access to services, basic infrastructure, and income generation opportunities. This multi-level deprivation also leads to high levels of crime and other illegal activities.

Delineation of the extent of the study area

Greater Khartoum is a large city. Studying urban deprivation at such a large scale is complex, as such two different scales of study area were defined. On one hand, a larger study area of the urban areas of Greater Khartoum was manually delineated, with the aim of creating generalized maps using freely available satellite imagery, for example land cover maps to help gain a wider understanding of the landscape of Khartoum. A broad area was delineated in order to include deprived areas on the outskirts of Khartoum that may become included as part of the city with future urban expansion. For guidance, this delineation used recent satellite imagery (Sentinel-2 imagery for 09/09/2020), and a number of existing datasets with differing definitions defining urban areas, or human settlements: WorldPop gridded maps of building patterns (Dooley Boo, Leasure and Tatem, 2020), GRID3 settlement extents (CIESIN & Novel-T, 2020) and Africapolis (OECD/SWAC, 2020). More information on these datasets can be found in Table 2.

On the other hand, for a more detailed analysis of deprived areas within Khartoum, two small scale pilot study areas were identified in order to develop and test IDeAMapSudan, with the participation of local communities in data collection, and production of detailed maps. The pilot study areas of Dar Alsalam (Omdurman), and Jebel Aulia were selected for their contrasting characteristics. Dar Alsalam concerns IDPs that used to be displaced elsewhere, but were then given ownership of planned houses in Alsalam, whereas Jebel Aulia is very old and inhabited by IDPs from South and West Sudan, or the Pantio neighborhood which is unplanned. Jebel Aulia has a large population with a significant proportion of refugees and immigrants from conflict areas, often settling in a spontaneous way. For the first phase of the project, the area around Jebel Aulia was selected as it suffers from socio-economic deprivation, but the western part of Jebel Aulia also has issues as it lies on the regularly flooded eastern bank of the White Nile. This frequent flooding also contributes to the vulnerability of the area. The delineation of the larger study area, and selection of the pilot study areas were presented to local experts within a workshop, to analyse their suitability.

Workshops for data needs assessment, stakeholder mapping and different EO approaches

In 2021, two expert workshops were held in Khartoum. The first workshop allowed for an information needs assessment, definition of the study area and understanding of deprivation domains. The second workshop deepened the understanding of what defines deprivation in Khartoum, gaps in locally available data and inputs for the selection of suitable EO methods for base maps. Workshops were attended by experts from ministries, NGOs and academia and held in hybrid format with a local and online attendance (due to COVID-19 restrictions). The second workshop focused on answering three main questions: 1) What is the definition of deprivation in Khartoum? 2) What are current and/or previous relevant projects/studies? 3) What are the major data gaps and information needs?

Local data collection in the case study area of Jebel Aulia

Jebal Aulia is one of the seven localities of Khartoum State located in the southern part of Khartoum city and bounded by the White Nile from the western side. The official census in 2008 reported its population as 942,429 which is about 18% of Khartoum's total population in the same year (Central Bureau of Statistics, 2009). As mentioned previously, Jebal Aulia is one of the key areas that received IDPs and it also suffers from recurrent floods causing major damages in infrastructure and households. In August 2021, three days were dedicated to collect local data in the field using a random sample of the study area (total sampled points 166 - accessible points 139). For the 139, a detailed observational survey was conducted that covered various aspects of physical and socio-economic deprivation. For each surveyed point, the location is described using a standard form and a photo is taken. For the data collection QField was used as an open-source app for collecting data that allows to load offline maps before going into the field.

Different EO approaches for the production of a base map of Jebel Aulia

EO imagery can be essential for understanding urban dynamics. However, it is necessary to extract meaningful information from an image in order to analyse it. The most common (geo) information extracted from EO imagery is that of land cover, i.e., the observed (bio) physical cover on the Earth's surface (Di Gregorio, A., 2005) based on their differing spectral characteristics. Maps of land cover (at different points in time) are essential for understanding the landscape (e.g., where are the built-up areas) and how and where this evolves over time (e.g., urban expansion). Besides basic physical information, also complex information (e.g., socio-economic conditions) can be extracted from EO imagery such as the location and characterization of deprived areas. There are many different methods for extracting such information. Many different aspects must be taken into account such as:

- the imagery available (spatial resolution, extent)
- the spatial unit to classify (pixel vs. object)
- the classification method (rule-based, machine learning, deep learning, etc.)

An analysis was carried out by the ToT team in Jebel Aulia, to test and compare different methods for the classification of land cover (including areas that might be slums or deprived). Three different methods were tested and validated by using data collected in the field:

- Method 1 → Object-based classification using very high resolution PlanetScope imagery and rule-based method of classification.
- Method 2 → Pixel-based classification, using Sentinel-2 imagery and the Random Forest algorithm for classification
- Method 3 → Pixel-based classification, Sentinel-2 imagery and the k-nearest neighbours method of classification.

Overview of the data ecosystem to city level modelling of deprivation

The Domains of Deprivation Framework guides the integration of different data that relate to multiple aspects of urban deprivation. The outputs are twofold: 1) a city-wide gridded map of deprivation on a continuous scale from most-to-least deprived (at a 100x100 m grid) and 2) a local detailed map that reflects neighbourhood level deprivation for the case study area.

The city-scale deprivation map allows to depict the spatial patterns of urban deprivation but also highlights specific domains (e.g., access to infrastructure). The input for selecting relevant domains and indicators are the results of the expert workshops that provided guidance on relevant deprivation indicators for Khartoum. For each selected indicator, available open and local datasets are selected and compiled into a data ecosystem for deprivation modelling. For the experiential phase, the data ecosystem is compiled at the Center of Expertise in Big Geodata Science (CRIB) at ITC. CRIB is a horizontal facility for big Geodata technology in education, research, and institutional strengthening activities. CRIB allows cloud computation of big data, which avoids computational constraints that have been limiting city scale analysis (in particular in resource constrained environments). The final data ecosystem will be locally available in Khartoum at a server that allows stakeholders to access, update and further develop the system. The neighborhood scale map of deprivation is informed by local data sets of the study area (Jebel Aulia), the EO base map produced for the study area and local field survey of the area. The local map provides a detailed localized characterization of a deprived community for developing localized policies. Furthermore, the local map allows for a comparison of the city scale map and an assessment of limitations of its output.

RESULTS & DISCUSSION

As the project is still ongoing, this section provides an overview of the preliminary results and discusses future work plans.

Delineation of the study area

The delineation of the general urban area of Greater Khartoum can be seen in Figure 2. Unlike the urban extent defined by the WorldPop (Dooley *et al*. 2020), a continuous area has been delineated in order to better understand the context and dynamics of the built-up areas with their surroundings. As for the suggested pilot study areas, the vast majority of the workshop participants agreed that Alsalam and Jebel Aulia were good choices as they provide different dynamics of deprivation. Their location of the suggested study areas within Khartoum can be seen below, as well as the final delimitation of the Jebel Aulia pilot study area used for the preliminary investigative analysis.

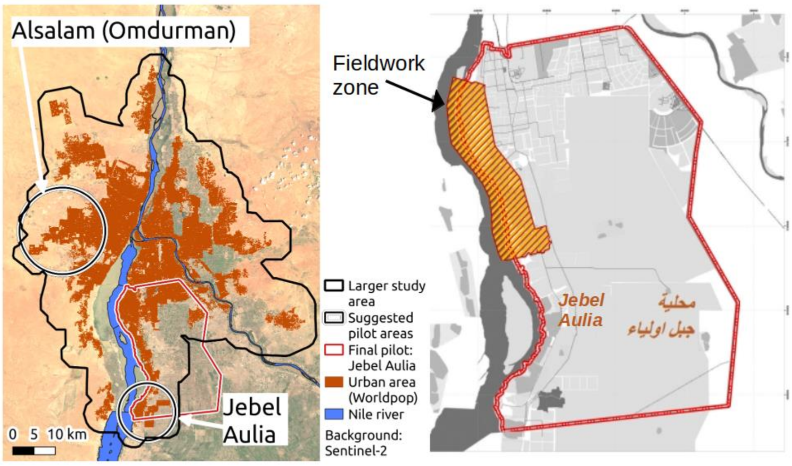

Figure 2: *Manual delineation of the larger study area, locations of the two suggested pilot study areas, final delineation of the Jebel Aulia pilot study area for fieldwork (by the authors).*

Selection of Deprivation Domains and Indicators

The IDeAMaps framework was used for the workshop held with local experts to identify domains and indicators that are locally relevant for the three scales, i.e., household, within area, area connect level. The workshop and expert discussion also provided an overview of ongoing local projects, which allowed us to identify four related projects (i.e., Land nexus 2018 -2020, Abo Adam Project to convert agricultural land into residential land, Urban poverty alleviation UNDP/Habitat – 1999-2000 and Mayo the path to resilience (GIS & EO)- June 2021). Four major data gaps and information needs have been concluded during the workshop:

- Social data (e.g., population, household characteristics and socioeconomic data)
- Flooding data
- Integrated and updated maps (most of the time maps does not reflect the actual status)
- Vulnerability map – fragile area map (with multiple deprivation domains).

Local Mapping of Deprivation using selected EO approaches

The analysis carried out by the ToT team in the pilot study area of Jebel Aulia produced three land cover maps, which can be seen in Figure 3. While the three methods provided land cover maps with high levels of accuracy, the analysis inferred that the Random Forest algorithm provided the best results for differentiating built-up areas from other classes, with an overall accuracy of 94%, but without any differentiation between formal or informal buildings. To discriminate deprived from other built-up areas high level image features like texture can support and be employed with deep learning.

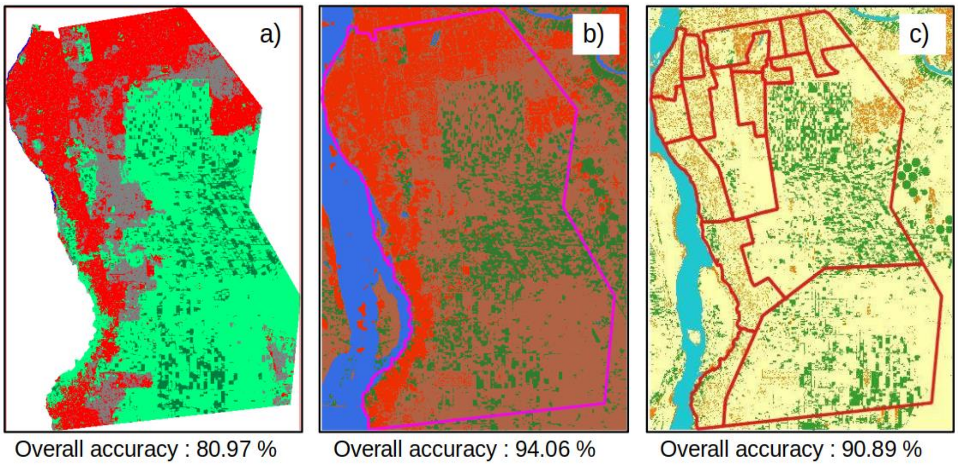

Figure 3: *Base maps of the study area. a) Method 1, b) Method 2, c) Method 3 (by the authors).*

Besides land cover maps, local data related to aspects of deprivation have been collected. This included local services, infrastructure and flood zones (Figure 4-right), results providing distance to services, infrastructure and had hazard susceptibility.

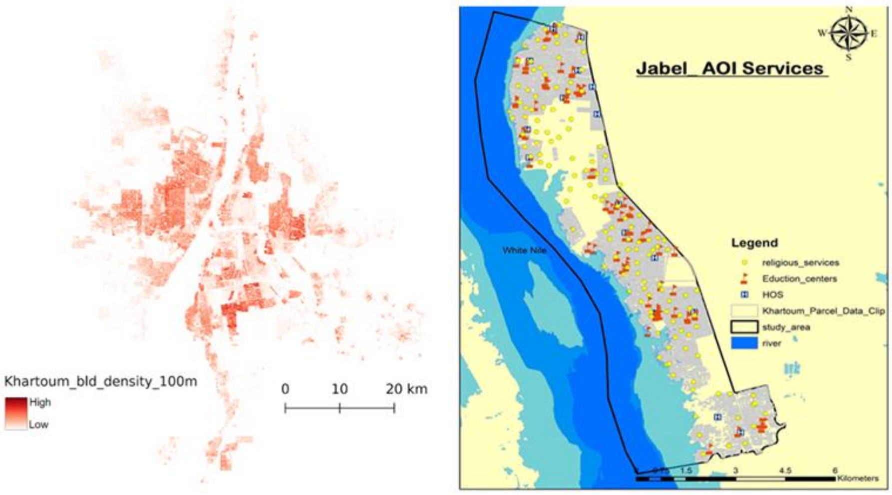

Figure 4: *Deprivation indicators at two scales, left: built-up density of Khartoum (unplanned urbanization domain); right: local survey results (by the authors).*

First data build in the data ecosystem and draft design of the data ecosystem

Based on the components of deprivation identified earlier, an inventory was compiled of open data which can be used to support deprivation mapping at a city scale (Table 2). These datasets have been compiled within CRIB. For example, built-up density (Figure 4-left) can be related to unplanned urbanization and is often a simple but useful proxy of deprivation. The next steps for the project will combine indicators to arrive at an overall deprivation index for the city of Khartoum.

Theme	Type	Description	Spatial resolution	Date	Source
Satellite imagery	Sentinel 2	High resolution imagery of the earth's surface as of 2015. Mosaic images can also be produced.	10-20m	from 2015	ESA (nodate)
	Sentinel 1	Radar imagery		from 2014	ESA (nodate)
	Elevation	Digital Elevation Model (DEM) of the Shuttle Radar Topography Mission (SRTM)	~30m	2000	NASA (2015)
	Nightlight	Images taken at night, at low resolution	500m	2016	NASA (2016)
Population	Worldpop	Grid cells of population count. Various different methods of calculation are available.	~100m	Annually from 2000	Worldpop & CIESIN (2018)
	Global human settlement population	Grid cells of population count	(~250m)	2015	Florczyk et al. (2019)
Urban / settlement areas	Worldpop	Gridded maps of building patterns (urban and rural). Thresholds defined if a group of contiguous cells have a minimum number of buildings (5000) or if there is a minimum number of contiguous built-up cells (1500)	~100m	2020	(Dooley et al. 2020)
	World settlement footprint	Global human settlement mask, WSF201**T**5	10m	2015	Marconcini et al, (2020)
	Global human settlement layers	Various datasets of the spatial distribution of (multi-temporal) presence of built-up areas, and different settlement typologies, and identification of urban centers, based on various sources (Sentinel-1, Sentinel-2, GHS population layer…)	Multiple (10m - 1km)	Multiple (from 2015)	Florczyk et al. (2019)
	Africapolis	Data on urban agglomerations in Africa. Based on a large inventory of housing and population censuses, electoral registers and other official population sources. Satellite and aerial images are used to inform on the physical evidence on the ground, that is the built-up area and the precise location of settlements.	N/A	1950 - 2015	OECD/SWAC, (2020)
	GRID3	Boundary extents of settlements (built-up areas, small settlements and hamlets). Thresholds defined based on building footprint density (>=13) and minimum built up area size (400,000m².	N/A	2020	(CIESIN & Novel-T, 2020)
	Google Open Buildings	Map of all building footprints in Africa (extracted from EO data and AI methods)	N/A	2021	Google
Land cover	CCI	Prototype high resolution land cover map over Africa based on 1 year of Sentinel-2A observations, from the Climate Change Initiative (CCI)	20m	2015-16	ESA (2017)
	Copernicus	Land cover maps and land cover fractions.	100m	2015 - 19	Buchhorn et al (2020)
	ESRI	Land cover map	10m	2020	Karra et al (2021)
Amenities / infrastructure	OSM	OpenStreetMap (OSM), multiple layers of buildings, roads, waterways, points of interest etc. Dataset is constantly being updated	N/A	2021	OpenStreetMap (2020)
	Health facilities	Locations of sub-Saharan health facilities	N/A	2020	WHO (2020)
Other	Administrative boundaries	Administrative boundaries levels 0-3 for Sudan	N/A	2018	GADM (2018)
	Flooding	Water observed by satellites for flood events (UNITAR). Provides PDF maps and vector data of surface water detected by VIIRS-NOAA around known flood events.	N/A	Multiple	UNITAR (2021)

***Table 2**: Overview of some of the main spatial datasets available freely online.*

Discussion - Towards building a spatial understanding of urban deprivation in Khartoum

Expert discussions and local field data collection revealed that local data on deprivation do not exist or are scattered within different local authorities and are inaccessible to inform planning and decision making. There is a continuously growing amount of datasets available, often EO data products or crowd sourced data (e.g., OSM). However, local authorities require skills, knowledge and the capacity to work with such data, understanding their scope and limitations. For example, how to optimally process and combine open datasets with local (often patchy and dated datasets). IDeAMapSudan aims to fill local data gaps and support urban policy towards addressing several of the SDGs (e.g., SDG 1 and 11).

Before entering the modelling phase of building deprivation models several pre-steps are required, this includes the definition of the urban extent and the local conceptualization of deprivation and the understanding of local information needs. To support the sustainability of the data ecosystem (presently under development), capacity development is required. At present, we have been training the capacity of technical and contextual experts (poverty and planning) to co-design and co-develop the data ecosystem. To further promote the sustainability of the data ecosystem, capacity development is focusing on FOSS that can be used by local organizations also after the completion of the project. After the first prototype of the deprivation ecosystem, a number of deprivation maps were produced by the team (Figure 5), showcasing the distribution of public services, environmental contamination and social hazards. Further training will focus on a larger group of staff of different ministries, NGOs and local academics to use the model outputs. In the future, we envisage the data ecosystem as a platform to exchange data and to communicate on urban deprivation related topics between government actors, NGOs and local academia. This will require a system design that deals with data ownership and privacy issues. For example, the rationale for using a 100x100 m gridded mapping system is to reduce privacy issues by not revealing household or personal data. Other questions, related to maintaining the system updated and ensuring FAIR data principles (Wilkinson et al., 2016), will be part of the next design stages.

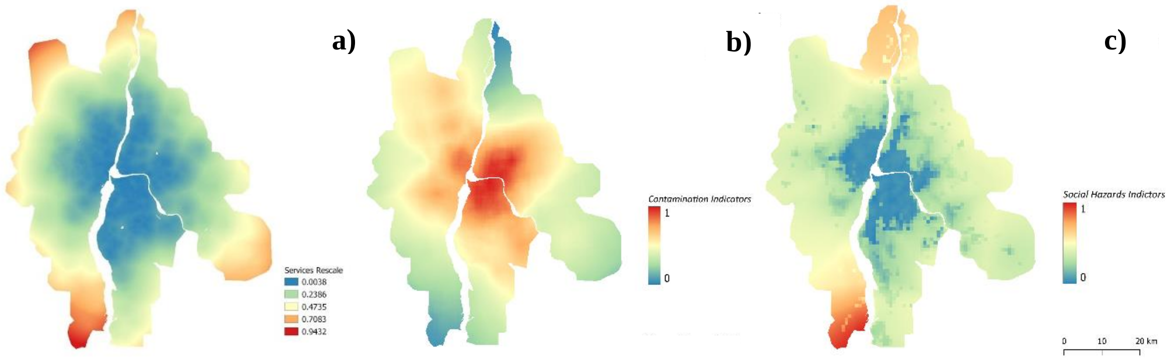

Figure 5: *Khartoum State Deprivation Maps a) public services, b) environmental contamination and c) social hazards (by the authors).*

CONCLUSION

The aim of this paper is to localize global knowledge on deprived area mapping with EO for Khartoum and presents the workflow to set-up the IDeAMapSudan network and data ecosystem. It considers the local needs, actors and data ecosystem to establish IDeAMapSudan as well as the capacity-building component to hone the technical skills required to set-up, maintain, and update the system. IDeAMapSudan addresses two major gaps in relation to urban deprivation data. First, we use available data (global and local) to provide data which are locally of high demand but do not exist to support planning and policy making to address SDG 1 ("No Poverty") and SDG 11 ("Sustainable Cities"). Second, we build the capacity of local stakeholders (from ministries and NGOs) to work with the data ecosystem depicted to support these policies. The combination of building required data, making them accessible to a wide group of local stakeholders and training their capacity will be the first step towards evidence-based policy making to addressing local SDG monitoring in a resource constrained environment.

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