RISE Planetary Health Data Platform: Applied Challenges in the Development of an Interdisciplinary Data Visualisation Platform

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Abstract: There is tremendous potential for digital landscape architecture to support actions within the international development sector, which operates in highly diverse and complex environments. Informal settlements, or slums, which often have limited access to basic services, are one such example. This paper presents the development of a Digital Platform within an action-research project, RISE, which aims to investigate the interlinkages of human and environmental health – planetary health, implementing a built intervention and measuring change over time. The platform prototype has been developed to simulate human and environmental contexts in the RISE project settlement sites and support informed decision-making by researchers, implementers, communities and agencies. It is anticipated that the health and environment data hosted within the platform will improve researchers' understanding of contamination exposure pathways and inform water sensitive urban design and infrastructure implementation in the RISE informal settlements.

Keywords: Informal settlement, planetary health, data visualisation platform, interdisciplinary, landscape architecture, action-research.

1 Introduction

The Revitalising Informal Settlements and their Environments (RISE) project is a large action-research program working at the intersection of health and environment. RISE is trialling a new water sensitive approach to water and sanitation management in 24 informal settlement communities across Makassar, Indonesia and Suva, Fiji. Using a randomised controlled trial (RCT) approach, the project investigates the interlinkages of human and environmental health – planetary health, implementing a built intervention and measuring change over time. RISE takes a holistic, landscape-driven approach to water, sanitation and hygiene (WASH) to informal settlement upgrading, using water sensitive urban design approaches to improve sanitation, drainage and flood management within these vulnerable communities (RAMIREZ-LOVERING et al. 2018).

Informal settlements are the outcome of rapid urbanisation and lack of resources in the cities of the Global South. Over one billion people live in these contexts, with limited access to basic services and infrastructure. The combined effects of poor sanitation, inadequate solid waste management practices and substandard or non-existing drainage in these communities result in contaminated environments contributing to poor health outcomes. Consequently, geography and spatial relationships are fundamental to understanding how environmental factors affect health. With their focus on space and geo-positioning, Geographic Information Science and spatial analysis methods are particularly appropriate for environmental health

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investigations. These have played an important role in environmental health studies for several decades (MAANTAY & MCLAFFERTY 2011). WASH projects and policies for informal settlement upgrading require appropriate investment from governments and other institutions. Funding decisions for informal settlement upgrading largely rely on government policies (SINHAROY et al. 2019). However, there is insufficient empirical data and evidence demonstrating causal links between human health and the physical environment – critical to confirm the efficacy and rationale for particular kinds of infrastructure and health investments. These data are often missing, difficult to collect, or inconsistent (CHAKRABORTY et al. 2015), making it difficult to use by decision makers and investors. Legitimacy of analyses and findings to support transformations and improvements are, in consequence, limited. The scale and scope of the problem is such that governments resort to delivering traditional sanitation and drainage, failing millions of citizens. With informal settlement populations growing dramatically, integrated planetary health information is critical for effective policy making and resource allocation. This paper presents a prototype of a web-based planetary health platform which attempts to address this issue by adopting and adapting state-of-the-art data gathering, analysis and visualisation approaches. The paper reflects on the development of the platform – established to enhance interdisciplinary research and project implementation – by integrating planetary health information in order to support informed decision-making by researchers and implementers.

2 Data and Methods

2.1 Platform Aims and Development

The platform aims to support researchers in making connections between human health and the physical environment. It does so to support decision making processes for the planning and delivery of sanitation and water infrastructure as well as the analysis of environmental factors which may impact on community health and well-being across intervention and control communities. The platform is implemented as a web service consisting of a 1) web-viewer frontend, and 2) GIS database backend with a permission system hierarchy.

Frontend

The web-viewer frontend will enable researchers to view and interrogate the large amounts of bio-physical and demographic data that will be collected in each settlement in an agile and spatially explicit visual manner (Fig. 1). The web-viewer frontend is primarily built around Cesium.js, 'an open source JavaScript library for creating world-class 3D globes and maps' (CESIUM JS n. d.). Cesium.js allows the platform to render 3D GIS data in a web browser and to overlay environmental sensing or household/settlement data at its geolocation. It also provides native time support, which accommodates time-series information for the multiple and diverse sampling rounds of the research program of datasets. For example, temperature and humidity data is collected using sensors over hourly periods throughout the project lifespan, while stools and bloods are collected at quarterly and annual intervals.

Backend

The database schema aligns spatial, environmental sensing, health-related and other data along three major axes-geospatial, time (using either household or settlement as linkage between human-related information) and location. The backend is a PostgreSQL database with

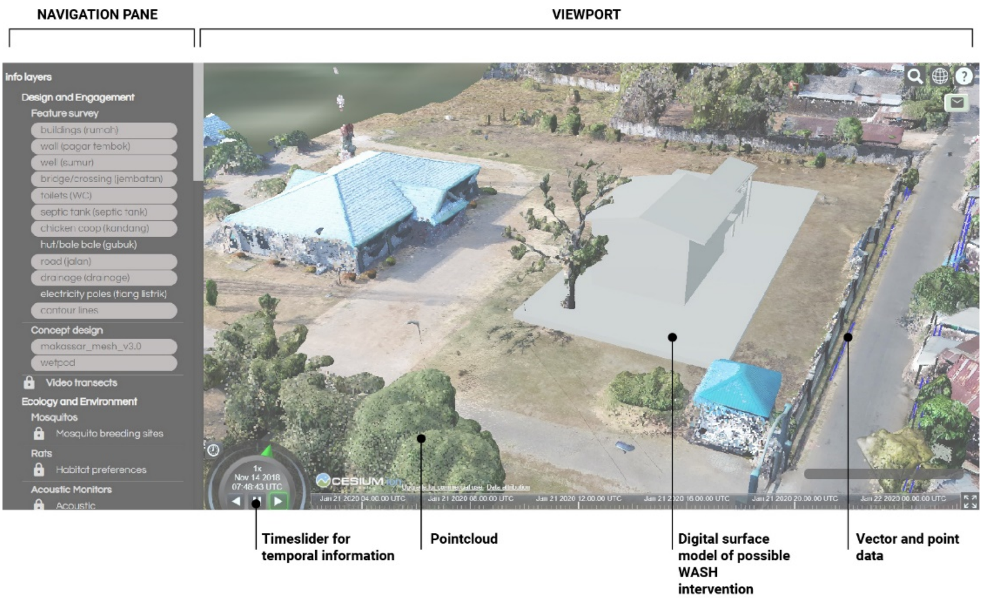

Fig. 1: The platform aims to support decision making through the integration of a range of spatially explicit datasets. These include vector and point data, as well as terrain (surface) data.

PostGIS installed. This is a 'spatial database extender for PostgreSQL object-relational database and adds support for geographic objects allowing location queries to be run in SQL' (POSTGIS n. d.). For example, over time, environmental and ecological information can be geographically embedded within the aerial and ground survey derivatives such as orthomosaic aerial imagery, digital surface models (DSM), point cloud and contour data.

Permission Hierarchy

During the platform development, special consideration has been given to a permission system which allows for permission hierarchies for different tables within the database. This allows for granular access settings of data. For example, environmental information, like temperature and rainfall, can easily be made publicly available, whereas certain health-related information, would have restricted access to follow proper ethics protocols.

2.2 Platform Data and Use

RISE is a seven-year research program (July 2016 – June 2023), with work divided into two core areas: 'Intervention' and 'Assessment'. The Intervention team is focused on the design, stakeholder management and delivery of the built intervention, while the Assessment team will measure the health and well-being of residents – particularly children under five years of age – and the ecological diversity of the surrounding environment (RISE PROGRAM n. d.) to gauge intervention performance and efficacy. The teams are interdisciplinary and international, with field and lab teams located in offices in Makassar and Suva, liaising daily with research partners in Australia, the United Kingdom and the USA. Based on the structure of the RCT, six of the 12 sites in Makassar and six in Suva will receive sanitation, drainage and flood management improvements within the first phase. The six 'control' sites in each city will be monitored throughout the research project, receiving the improvements in the second phase, after the assessment period is complete.

The Intervention team includes researchers and practitioners from the fields of landscape architecture, architecture, ecology, hydrological and civil engineering, and planning. They work closely with in-country team members in Makassar and Suva from the fields of architecture, engineering, community development, and social sciences. These teams are responsible for establishing the baseline spatial data for settlements and recording changes in built environment across the lifespan of the project. Through the participatory design of the intervention – undertaken with the communities – the team also seeks to understand and incorporate community dynamics (organisation, power, family relationships), WASH challenges, and land ownership/tenure arrangements. Consequently, the diverse datasets that must be collected, managed, and used include: cadastre from local authorities (where available), remotely-sensed aerial survey (drone) and ground feature survey, field observations, focus group discussions, and household interviews and surveys etc. The resulting intervention – which goes beyond household-level water and sanitation provision to deal with the whole environment in which people live – is an entanglement of social and technical aspects (RAMIREZ-LOVERING et al. in press).

Meanwhile the Assessment team is divided into the following areas: ecology and environment; human health; wellbeing; and policy and investment. This includes managing and collecting point data from neighbourhoods, for example: environmental data on ambient conditions within the community, such as temperature and humidity, acoustics, soil and environmental waters, and the prevalence and type of mosquitoes; and community and household data, such as blood and stools (for monitoring gut health in children < 5), demography and wellbeing (RISE PROGRAM n. d.).

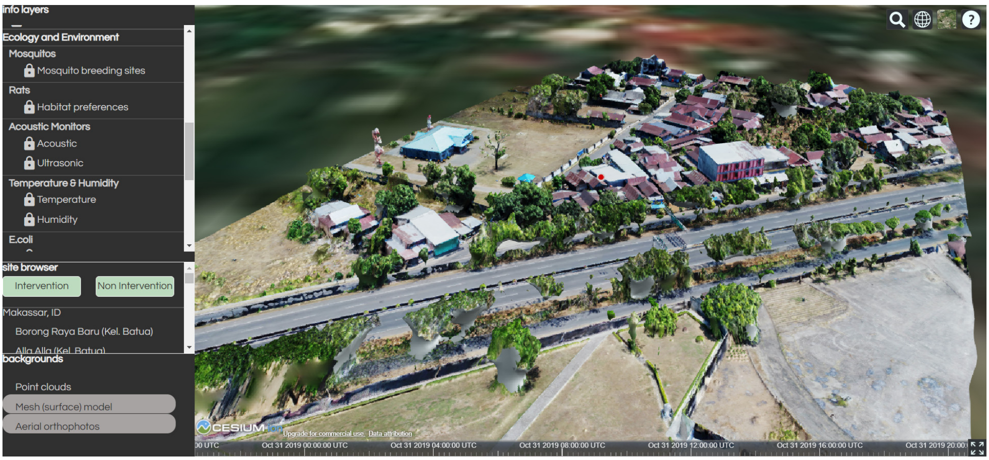

Fig. 2: Screenshot from platform prototype illustrating georeferenced, high resolution 3D mesh model overlaid into open-source satellite imagery

Across both teams, spatial-temporal information in the form of baseline and post-intervention data across the 12 sites is important. The platform serves not only to integrate the various datasets from the Intervention and Assessment teams but also allows for monitoring and assessment over time in a visually accessible manner.

Figure 2 illustrates the web-viewer frontend of the platform. On the left-side is the navigation pane which is divided into three sections, namely the info layers, site browser and backgrounds. In the info layers pane, the user can navigate through subsections for datasets managed by either the Intervention or Assessment teams. For example, the datasets overseen by the Ecology and Environment assessment team include temperature and humidity data, as well as point data relating to rodent and mosquito populations. In the site browser, filters for 'intervention' and 'non-intervention' (control) sites can be toggled on and off, and the user can navigate to individual sites in the cities of study. In the backgrounds pane, the data can be viewed in 2D mode by turning on the aerial orthophoto as the background, or navigating in 2.5D with the point cloud or DSM, which can be overlaid with the orthophoto if desired. A timeslider runs along the bottom of the panel, and has play forward, reverse and pause functions to display temporal data.

Fig. 3: Screenshot from platform prototype illustrating selection of a building to query household data on water, sanitation and hygiene factors

The interactive viewport on the right side displays the remotely-sensed and point data sets which is toggled by the navigation pane on the left side of the viewer. Researchers can layer relevant datasets together and query geographically located data points embedded within the site (Figure 3). In so doing, this will facilitate the complex engagement and communication between RISE researchers and in-country teams, as well as project partners, government stakeholders and communities, in order to facilitate interdisciplinary and multi-country collaboration and built intervention design and delivery. The user end platform functionality is elaborated further in Table 1.

Table 1: The table describes user end platform functionality through a number of examples. The platform aims to support complex engagement and communication between RISE researchers, in-country teams, project partners and stakeholders in order to facilitate built intervention design, delivery and assessment.

USER END PLATFORM FUNCTIONALITY	
Functions	**Example**
Undertake desktop site visits and view 3D models and geospatially referenced data.	Built environment data (such as buildings, access and circulation networks, services and utilities), natural environment (such as exposure sources and pathways, vegetation types and coverage, and hydrology), and household and community demographic data.
Explore critical information relative to the delivery of the intervention in a spatially-explicit manner.	Hotspot mapping, water stressors mapping, identification of contamination sources and pathways. Baseline ortho-rectified maps and aerial photogrammetry models to compare current and proposed urban environment, taking into account designed landscape and infrastructure interventions.
Improve engagement with other teams with visualisation tools.	Visual platform to refer to in cross-team meetings and with in-country teams, which include team-members from other disciplines (health, biology etc.).

3 Discussion

Activities conducted so far in the prototyping of the Data Platform range from technical aspects of acquisition, data processing, analysis, and visualisation; to engaging with researchers and in-country team members around functionality. In its current stage, a range of challenges have been experienced insofar as the platform has attempted to simulate human and environmental conditions in order to support analysis and decision making, enhancing interdisciplinary research and project implementation.

First, given the interdisciplinary nature of the RISE project, in order to develop the platform, the following factors have to be taken into account: dataset interoperability, interdisciplinary workflows and timeframes (availability of research data for integration). For example, the manner in which data is archived and used differs significantly between the Implementation and Assessment teams which include a range of researchers from different disciplines gut health – environmental science and ecology, medicine, social sciences and the built environment.

Second, the nature of the project as an RCT with its related health components, and the vulnerability of populations under study, mean that project data needs to be managed sensitively. While at the structural level data access is managed based on institutional research protocols, the platform aspiration to deal with geo-located data means that standard anonymisation techniques for health data are insufficient when data is linked to geospatial information like settlement or household identifiers. Additionally, through community workshops for the design of the intervention which capture information on boundaries and water supply, among others, it has become evident that other kinds of information can also be sensitive (for example relating to community power dynamics and land tenure) within the context. During the prototyping phase, potentially sensitive data has been scrambled and steps have been taken to lockdown particular datasets and establish user profiles with access rights based on researcher requirements.

Third, the intention was to develop a web-based platform that could be used outside the institution or office, from a laptop or tablet. A range of challenges were experienced relating to accessing the model while working from the local office in Fiji. Researchers would utilise mobile data plans with comparatively limited download and upload speeds and at times limited network coverage. Mechanisms for improving load times and operability such as tiling models, level-of-detail techniques to reduce the workload on the graphics pipeline, and data caching are being explored. For the former, although open standards for model tiling have been endorsed by the Open Geospatial Consortium in 2019 (OPEN GEOSPATIAL CONSORTIUM 2019) and are adopted by major vendors of photogrammetry software, the existing dataset has not been optimised for such format. For the latter, the issue of data security will need to be carefully addressed.

4 Conclusion and Outlook

With informal settlement populations growing dramatically, integrated planetary health information is critical for effective policy making and resource allocation. The paper has described data platform prototype that seeks to address this gap, and begins to deal with some of the emergent challenges. Health and environment data can be integrated in the platform to improve understanding of exposure pathways (e. g. water-borne diseases due to flooding) and inform water sensitive urban design and infrastructure implementation in the second phase of RISE settlements.

While beyond the current scope and intent of the action-research program, the platform has the following aspirations to use the platform to engage with local stakeholders and decision-makers, empowering them with access to and visualisation of located information:

1) The precise aerial imagery of previously un-surveyed informal settlements would enable the interpolation of accurate elevation models. Nesting information from multiple sources (sensors, agency datasets) will address gaps and inconsistencies in conventional datasets, providing opportunity to simulate exposure pathways and validate the use of community-reported data for upscaling and replication.
2) At neighbourhood-scale, communities can be empowered to collect environmental data and be equipped with information to support discussions about their challenges. Through this involvement, improvements in health and well-being are anticipated as individuals' understanding of the connection between their health and the environment increases.
3) At city-scale, local decision-makers could be empowered with access to open source cloud-hosted analytical and visualisation tools. Better-informed stakeholders could lead to a number of potential benefits, including: more effective prioritisation of infrastructure projects; supported learning from successful projects; and, stronger advocacy for essential services.

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