6 Cross-Continental YouthMappers Action to Fight Schistosomiasis Transmission in Senegal

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Abstract

The authors detail the design of an innovative and cooperative approach to ground truthing geospatial data through cross-continental YouthMappers coordinated action. This effort provided key geographic information to design control actions and served as a powerful, active tool to disseminate awareness about the importance of neglected tropical diseases in remote regions of the planet in support of SDG 3 Good Health and Well-being and SDG 6 Clean Water and Sanitation.

Keywords

Sanitation · Pathogens · Habitat · Global collaboration · Senegal · Italy · Health

1 The Complex Transmission Cycle of Schistosomiasis

In many regions of the world, the relationship between humans and the environment is troublesome, as it can give both access to natural resources and exposure to pathogens. Human intervention associated, for instance, with expanding urbanization and the construction of infrastructure can destabilize ecological equilibria, causing at the same time easier access to resources and higher exposure to environmentally transmitted diseases. Examples of this twofold relationship can be found in many regions of the world, including Saint-Louis, located in northwest Senegal, West Africa, where an increase of schistosomiasis transmission has occurred between 1996 and 2016, according to

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data at the Ministry of Health. This event followed the construction of the Diama dam, which was designed mainly to prevent saltwater intrusion into the Senegal River.

Schistosomiasis belongs to the group of the so-called neglected tropical diseases (NTDs), a diverse group of infections that in 2021 was still globally affecting more than 1.7 billion people according to the World Health Organization (Neglected Tropical Diseases progress dashboard, WHO 2021). The adjective “neglected” qualifies diseases whose burden is overlooked by the relevant decision-making bodies, leading to continuing and possibly widespread transmission in developing regions and in the poorest groups within developed countries. In particular, the 2030 UN Agenda for Sustainable Development Goals (SDGs) identifies the target of ending NTDs as SDG 3.3, whose associated indicator (3.3.5) is the number of people requiring interventions against them. Just to have an idea of the numbers involved to date at the global scale, the progress dashboard of WHO (2021) also reports that in 2019 alone, 230 million people were affected by schistosomiasis globally, 90% of whom lived in Africa. Action items to try solving this issue consider the increase of political commitment to sustain domestic financing, development of new drugs, and creation of mapping systems to target treatments and monitor drug resistance. In this chapter, we show how cooperative YouthMappers action can at the same time (*i*) provide key geographic information to design control actions (such as identifying the most vulnerable villages that may be afflicted by schistosomiasis) and (*ii*) serve as a powerful, active tool to disseminate awareness about the importance of NTDs in remote regions of the planet.

Schistosomiasis is a water-based disease with a complex transmission cycle (Fig. 6.1). Human exposure is determined simply by contact with freshwater where the intermediate host (snails of genera *Biomphalaria* or *Bulinus*) of the parasite (worms of genus *Schistosoma*) lives. Humans are definitive hosts of schistosomes, which sexually reproduce in the bodies of infected people, who then release worm eggs with their excrements. Eggs hatch into miracidia, a free-living stage of the parasite that can infect snails. Schistosomes undergo asexual replication in infected snails,

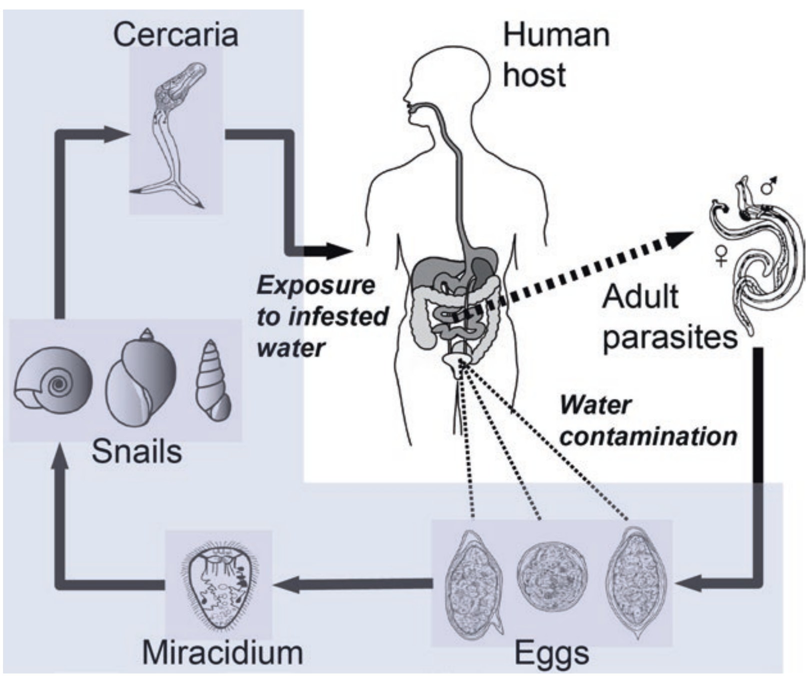

Fig. 6.1 The complex transmission cycle of the water-based disease named *schistosomiasis*. (Mari et al. 2017)

which then release cercariae, another free-living form of the parasite. Cercariae close the transmission cycle by penetrating the skin of humans and other animals who enter in contact with infested water. Schistosomiasis can cause urogenital and/or enteric problems in human carriers and, in children, may determine serious impairment of body growth and mental development, leading to a run-down state and preventing regular school attendance, a first step into (or a key step to perpetuate) a disease-induced poverty trap (Bonds et al. 2010). The focal human populations affected by this disease are in fact those who (*i*) already live in extreme poverty conditions, (*ii*) need to draw and use water directly from possibly contaminated environmental sources (Fig. 6.2), and (*iii*) may also release their wastes directly into the environment, thereby contributing to onward transmission and maximizing the probability to become infected.

In the Saint-Louis region of Senegal, anthropogenic interference with the natural ecosystem was linked to an increase in the snail population size, particularly around Lac de Guiers, the largest lake in the area (Sow et al. 2002). As a consequence, there has been a rehearsal of cases of schistosomiasis within the Saint-Louis region. To help health authorities improve the resilience of vulnerable populations, a deepened, quantitative understanding of disease transmission dynamics, accounting for both socio-economic and environmental variables, is fundamental. For this purpose, geospatial information is key, as it allows mapping locations where human and snail hosts reside, which is rural villages where vulnerable people live and the snail habitats where disease vectors are potentially most abundant. Furthermore, the creation and maintenance of open data repositories allow both local and remote citizens to actively participate in these challenging activities, namely, by collaboratively extracting information, sharing knowledge, and sensibilizing the local population about the risks related to schistosomiasis. This was the main

Fig. 6.2 A mother enters natural waters possibly contaminated by *Schistosoma* parasites to wash clothes, with children assisting her and playing within water in Ndiawdoun village. (www.openstreetmap.org/#map=19/16.06791/-16.39380)

motivation for us to participate in the 2018 YouthMappers Research Fellowship program with the project "Cross-continental YouthMappers fighting schistosomiasis in the Senegal River Valley," whose activities are summarized in the present chapter. We emphasize that the spirit of international cooperation among YouthMappers that we experienced during the Research Fellowship Symposium at the George Washington University and West Virginia University provided an important burst to realize the project as described here. After that event, in fact, we directly contacted the YouthMappers chapter at Université Gaston Berger (UGB) in Saint-Louis and asked for collaboration. Their answer was so enthusiastic that we decided to form a team to simultaneously map from three connected units in three locations (and two continents, Europe and Africa). The three units were PoliMappers (the YouthMappers chapter of Politecnico di Milano in Milan, Italy), UGB YouthMappers (the YouthMappers chapter at Université Gaston Berger in Saint-Louis, Senegal), and the PhD students at the African Institute for Mathematical Sciences (AIMS) in M'bour, Senegal. This last group was coordinated by one of us (Amadou Lamine Touré), who serves since years as researcher at the AIMS and spent one year as postdoc at the Politecnico di Milano within the Polisocial project "Mapping Schistosomiasis Risk in the Saint Louis region in Senegal" (MASTR-SLS, 2016). The diversity of experience and the multicultural background of the team resulted in a formidable facilitation of activities (other than fun).

2 Data Collection to Fight Transmission

We organized our geospatial data collection campaign in the following way. On one side, we started mapping the snail habitat: we performed field surveys in Senegal to retrieve multispectral drone imagery, also involving local mappers, in order to create a spectral signature to identify *Typha*, an aquatic genus of reed that is often associated with the presence of freshwater snails (Chamberlin et al. 2020). On the other hand, we mapped the "human habitat": OpenStreetMap (OSM) was fed with information about the villages where vulnerable people live. Many of these small and informal settlements are indeed unknown, even to the local government.

2.1 Mapping the Habitat of Snails

To identify *Typha* vegetation and possibly use that information to run eco-epidemiological models for schistosomiasis, it may be important to accurately describe the spectral signature of the aquatic reed. This would simplify habitat identification at wider spatial scales because large areas can be explored using drone or satellite images instead of field campaigns. The knowledge on the location of such vegetation is a valuable proxy to produce risk maps of schistosomiasis, as *Typha* may serve as habitat of the intermediate snail host of schistosomiasis. An accurate spectral signature of the reed can be obtained through surveys with drones equipped with multispectral sensors, typically used for precision agriculture.

In March–April 2019, thanks to the 2018 YouthMappers Research Fellowship and to the Polisocial Award by Politecnico di Milano (project MASTR-SLS, 2016), we had the opportunity to conduct an extensive ground-truth retrieval campaign. During this experience, we explored the rural region around the city of Saint-Louis to find spots of *Typha* (Fig. 6.3). Thanks to preliminary mapping of *Typha* areas in the region made by a local company (Fig. 6.4), our team had an initial hint of the places where the vegetation potentially grew. As the team was based in the city of Saint-Louis and a significant amount of time was required to reach remote areas of interest, the duration of the set of batteries of the drones was not sufficient to cover daylong survey activities, and regular trips from and to the city had to be planned. Different spots of *Typha* have been visited, in particular, near the delta of the Senegal River and the city of Saint-Louis. Rural villages and small inhabited places are dispersed all along the way. People in rural

Fig. 6.3 The YouthMappers field team consider a potentially contaminated area and stop to take a selfie via drone while crossing a waterfield with *Typha*

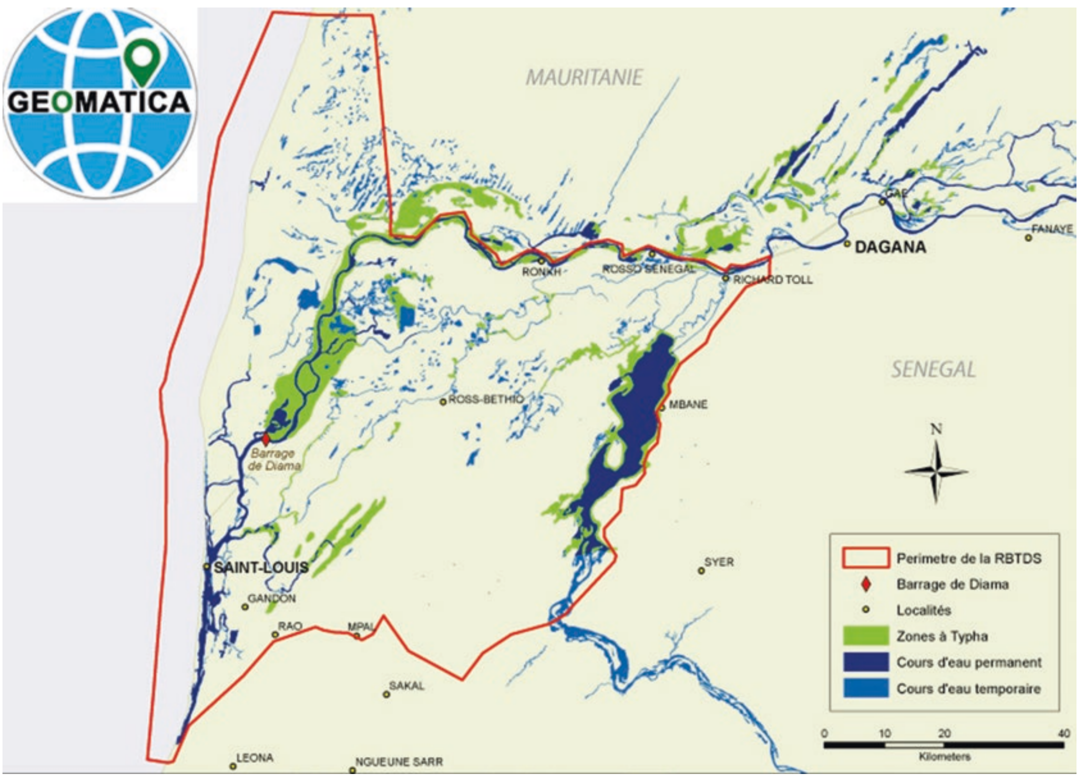

Fig. 6.4 The distribution map of *Typha* as qualitatively estimated by the UGB startup Geomatica serves as a basis for *Typha* scouting in the region

places enter rivers and water points to retrieve water for daily activities and domestic uses and to release wastewater, exposing them to high risks of being infected by schistosomiasis (see again Fig. 6.1).

During the first days of exploration, the team got in contact with people living in the study area's villages. The multicultural diversity of members in the team was very beneficial to engage local populations. Thanks to the presence of both Senegalese and Italian "YouthMappers with drones" members, the team had an empathic relation with inhabitants in the local language (Fig. 6.5). Even though the official language in Senegal is French, a large part of the population living in cities and the totality of the population living in rural areas typically speak Wolof, the most widespread language in West sub-Saharan Africa. The team (Fig. 6.6) had the possibility to explain the goals of its work, to inform the population, and to take drone surveys after having properly asked the permission of the chiefs of the different rural settlements.

Fig. 6.5 Children in a village are proud to hold our strange technical bird, the multispectral drone

Amidst the necessary adjustments, the first week of fieldwork did not lead to significant advancements in terms of ground truthing, as we only sporadically found spots of *Typha* and those were mainly mixed with other vegetation. A huge help was given to us when we entered in contact with researchers at Université Gaston Berger, more precisely with the group led by Dr. Elhadji Babacar Ly and Dr. Diene Ndiaye. They study the possible use of *Typha*, which has been found to have good thermal and mechanical properties, as a construction material (Ly et al. 2019), similar to what is done with bamboo in Asia. Members of the local university staff could indicate clearly where *Typha* was causing serious problems in the region, independently of the epidemiological issue. The team was guided through the agricultural zone of Saint-Louis near Université Gaston Berger, where the presence of *Typha* is so massive that most of the canals and drains are clogged, and local cultivations suffer from scarcity of water, whose flow can be altered by reed swamps. Efficient ways to remove big spots of such vegetation have been studied (Hellsten et al. 1999), but the proposed methods are costly. Indeed, several efforts are undertaken by the local government to reduce the effects of *Typha*, namely, by removing it by means of diggers (Fig. 6.7).

Since our goal with this drone-guided exploration of the region was to fingerprint the multispectral signature of *Typha* vegetation, areas like those in Fig. 6.3 were very useful spots to fly via the drone. To gather multispectral images of "non *Typha*" yet "*Typha*-like" vegetation data that would be instrumental to calibrate a classification model, the team also visited places where *Typha* was naturally absent, like the sugarcane fields in the northernmost part of the Saint-Louis region. In the end, the team had the possibility to visit Université Gaston Berger and to meet again

Fig. 6.6 The drone-mapping team greets the camera, from left to right: Amadou Lamine Toure, Michael Montani, Fabio Cattaneo and Ibrahima Sory Diallo

Fig. 6.7 Reducing the risk of exposure to the disease is possible via mechanical removal of *Typha* in the region surrounding Universitè Gaston Berger. (www.openstreetmap.org/#map=18/16.03875/-16.41664)

with the UGB YouthMappers, sharing mapping knowledge and experiences.

2.2 Mapping the Habitat of Humans

This task was carried out by setting up an extensive collaborative mapping campaign to create new OpenStreetMap data for the focal areas of interest involving YouthMappers and interested citizens from different continents, thereby fostering international collaboration among experienced and new mappers.

To identify the most vulnerable villages that may be afflicted by schistosomiasis, the mapping campaign focused on the extraction of buildings over the western part of the Saint-Louis region and around Lac de Guiers. The collaborative project was posted on the TeachOSM Tasking Manager for every OpenStreetMap (OSM) volunteer to contribute to. Moreover, several mapping events were held to achieve global participation in the production of open geospatial information for our focal area. The project was officially launched at State of the Map 2018 (SotM), the annual international conference about OSM and its community, which took place at Politecnico di Milano in July. Since then, we organized and hosted several editing gatherings with a variety of mapping groups, ranging from inexperienced volunteers to geoinformatics experts, with ages ranging from high-school teenagers to university students.

The main event, which we named "Cross-continental YouthMapathon," was organized involving three different gatherings mapping on the project simultaneously yet in different geographic locations. Each of these three local meetings was led by members of the MASTR-SLS project, who shortly introduced the research problem to the participants. Specifically, the three main poles were organized as follows:

- Politecnico di Milano (Milan, Italy), with Michael Montani and Lorenzo Mari, and the participation of the members of PoliMappers
- Université Gaston Berger (Saint-Louis, Senegal), with Fabio Cattaneo and Renato Casagrandi, and the fundamental contribution and collaboration of the local chapter of UGB YouthMappers, led by Ibrahima Sory Diallo
- African Institute of Mathematical Sciences (M'bour, Senegal), with Amadou Lamine Touré leading a group of students and staff members

Other YouthMappers chapters joined the mapping activity from other locations, for instance, Semillero GeoLab UdeA, based in Universidad de Antioquia, Medellìn, Colombia. As a result, our cross-continental youth mapping activity did involve three continents: Africa, Europe, and South America.

3 Results of a Cross-Continental Effort

3.1 Insights from Drone Mapping

The field mapping campaign led us to retrieve up to 28 square kilometers of high-resolution drone imagery, which allowed us to better define the spectral signature of *Typha*, notably on the green, red, and near-infrared bands. The dataset is composed of drone images taken during surveys of spots with *Typha* plants alone, with *Typha* mixed with other vegetation, or without *Typha*, like sugarcane farmlands. Specifically, the information coming from the imagery of *Typha* spots has been used to describe the spectral signature of the aquatic reed. As a first exercise, we applied machine learning techniques, notably logistic regression, decision tree, and random forest, to train classifiers aimed to identify *Typha* presence from drone imagery in images that were not used as training data for the construction of the algorithms. We avoid

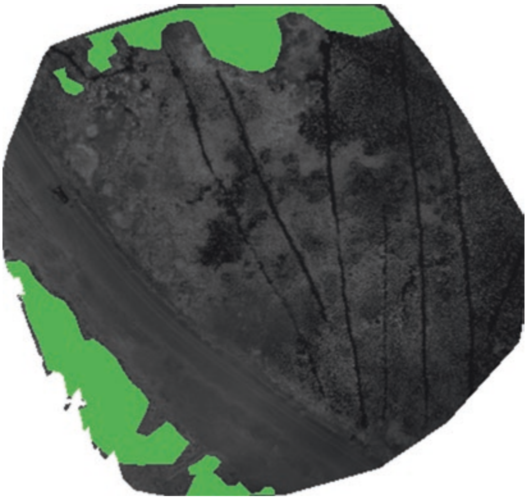

Fig. 6.8 Manually identified *Typha* are groundtruthed (in green) on a drone survey

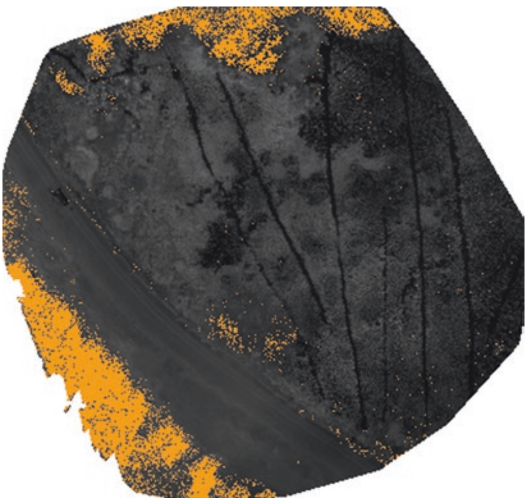

Fig. 6.9 Pixels predict *Typha* (in orange) from a Random Forest model trained on our dataset from another drone survey

detailing here the methodology used and the details of the analysis, which is still undergoing. In some of the areas, we had quite a good result in matching the true presence of *Typha*, as shown in Figs. 6.8 and 6.9.

3.2 Insights from OSM Mapping

The OSM mapping campaign lasted from July 2018 to November 2019. During the entire mapping campaign, a total of 23,165 buildings (from now on, edits) were mapped by a total of 240 different contributors from all over the world. Approximately 80% of the edits are geographically located in the Saint-Louis region, while the remaining ones are in Louga, the adjacent region to the South. Two simple queries to the OSM database about the status of the map in the focal region of interest at the beginning and end of our project can reveal the entity of our contribution (Table 6.1).

The corresponding map snapshots show the situation before (Fig. 6.10) and after (Fig. 6.11) our mapping campaign, in terms of buildings edited in Saint-Louis within the project.

Besides the sheer increase in the number of mapped buildings, participative mapping campaigns also offer the opportunity to study the emergent collective behavior of the participants. The goal of collaborative mapping is indeed not only to build maps but also to build mappers, as brilliantly summarized in the YouthMappers vision. And that is of primary importance to all of us. The cumulative distribution of OSM edits performed by all volunteers during the mapping campaign is reported in Fig. 6.12.

It is possible to notice how the steepest ascents occur exactly at the time of our major mapping events. Typically, those are named "retaining edits", that is edits occurring from the date of the event up to a few days later, as contributors often

Table 6.1 Summary of the mapping contribution of our campaign

Area of interest	Total buildings on OSM	Buildings we mapped (our edits)	Our edits over total	Increase
Senegal	282,016	23,127	8.2%	+9%
Saint-Louis	74,773	18,791	25.1%	+33.6%

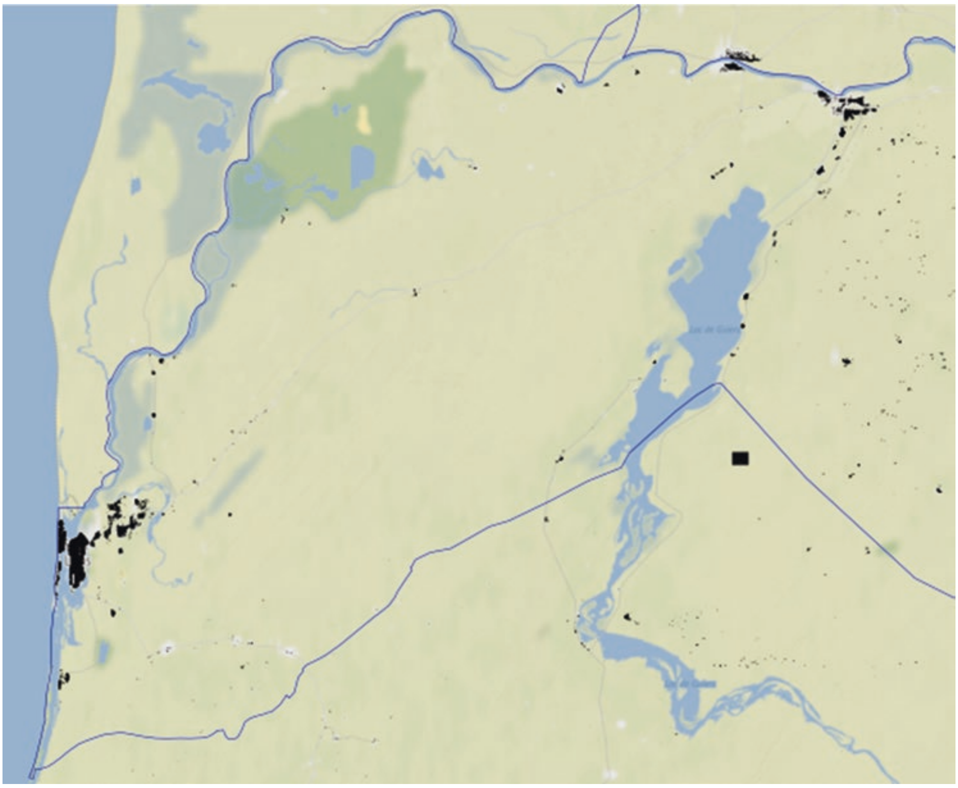

Fig. 6.10 Mapped buildings in the Senegal River Valley Region appear as black marks in the left panel before the project, shown as OSM data retrieved on 1 July 2018

kept on mapping well after the formal meetings. The statistics related to each major event are summarized in Table 6.2.

An interesting aspect of the statistics is the average number of edits per contributor at each event, which was much higher in meetings attended by expert mappers than it was in events aimed at beginners. While the expert mappers attending the SotM or NoG events were already proficient at OSM editing, the IAT event and PoliMappers@Statale gathered people who, in some cases, did not even know what mapping is. In the latter case, the expected edits-per-contributor ratio and retention are obviously lower.

We also estimated that up to 5901 mapped buildings within the project are not related to any of these major events, as they have been probably contributed by occasional mappers either on a voluntary basis or through small meetings not directly supervised by us. This unsolicited yet highly appreciated effort corresponds to 25.4% of the total edits—a “spillover” effect that is always hoped for but never to be taken for granted when launching collaborative events.

It is possible to further describe the behavior of volunteers by classifying them with respect to their past mapping history (if any) and contributed edits within our project. To this purpose, we identified four categories of users:

- *Newcomers*: People who did not know anything about OSM and never mapped earlier in their life
- *Mayflies*: Newcomers who mapped only on the day on which they joined OSM but did not contribute further to our project
- *Regular mappers*: Contributors who already knew how to map and participated regularly in OSM events
- *Power mappers*: Expert contributors who added way more features than regular mappers

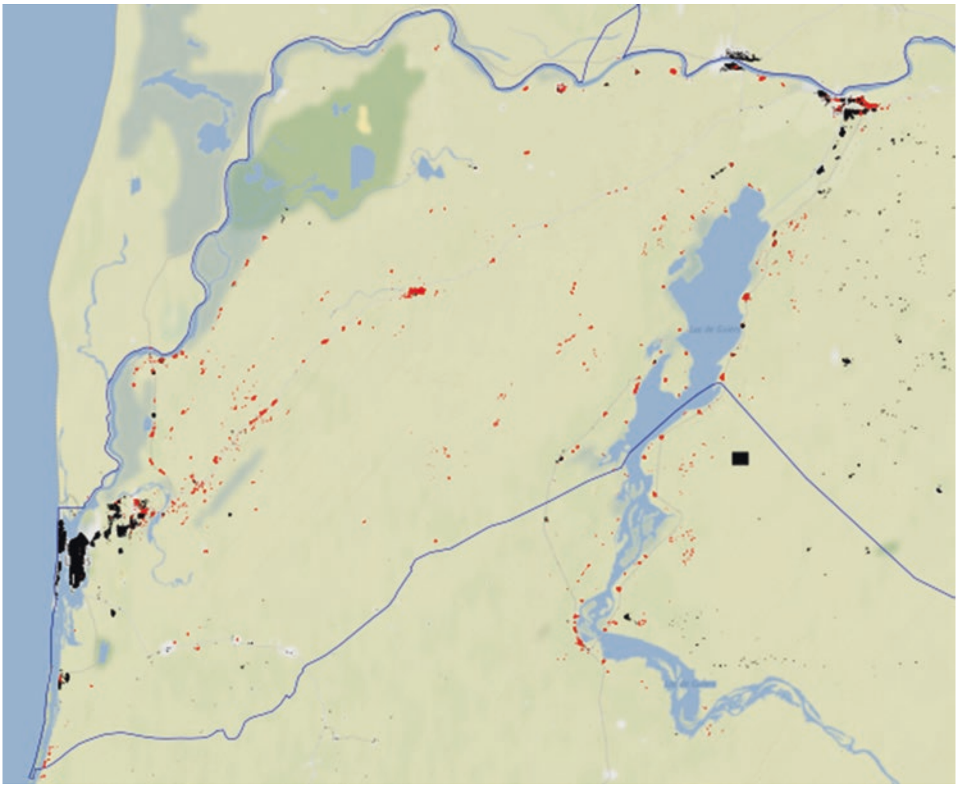

Fig. 6.11 Mapped buildings appear after the project as red marks in the OSM data retrieved on 26 November 2019

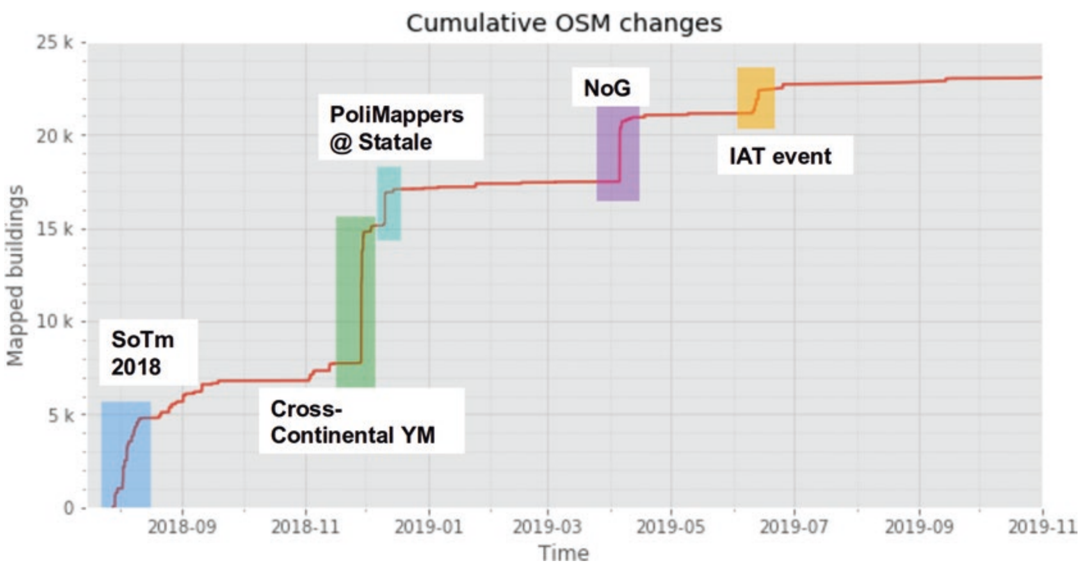

Fig. 6.12 Cumulative distribution of OSM changes performed by all volunteers during the mapping campaign show a step-wise increase in the phases of the effort

Table 6.2 Statistics of mapping contributions by event

Event name	Date	Retention[a]	Edits	Contributors	Average edits per contributor
State of the Map 2018 (SotM)	July 28, 2018	14 days	4762	15	317.47
Cross-Continental YouthMapathon	November 28, 2018	2 days	7053	71	99.34
PoliMappers@Statale	December 10, 2019	1 day	1691	26	65.04
Night of Geography 2019 (NoG)	April 5, 2019	3 days	3254	29	112.21
Ingegneria per l'Ambiente e il Territorio (IAT) event	June 13, 2019	2 days	504	18	28.00

[a]Retention is defined as the time for which there have been above-average crowdsourced OSM contributions after the event date

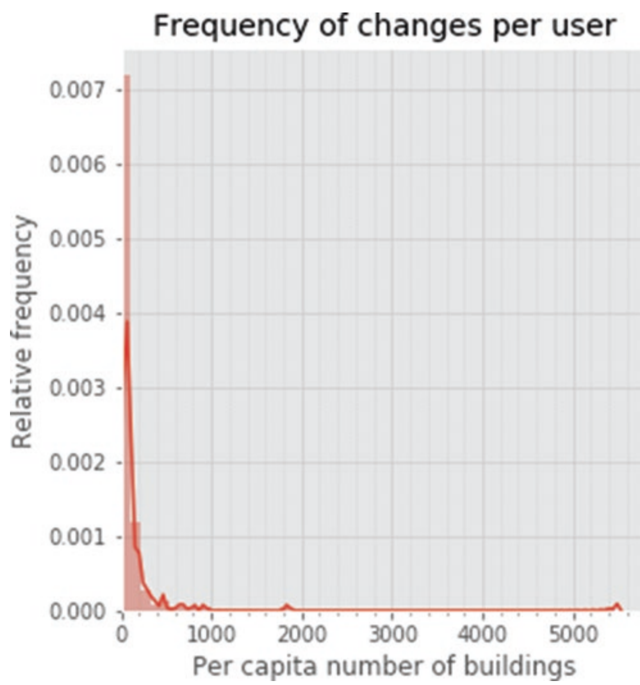

Fig. 6.13 Relative frequency distribution of the per capita number of changes on OSM are shown above

We recorded a total of 41 newcomers who joined OSM, thanks to our mapathons, via approximately 90% of which (36 people) were mayflies too. Even though the large majority of newcomers who discovered OSM stopped mapping, 10% of them did not and kept on contributing, possibly a first step into a long-lasting relationship with OSM editing and, hopefully, with introducing other people to mapping. This is the case of a Senegalese UGB student, who, after participating in the Cross-Continental YouthMapathon event, created a new mapping group in his home city, Richard-Toll.

The overall distribution of edits per contributor turned out to be far from normal, being instead well approximated by a power law with an exponential cutoff (Figs. 6.13 and 6.14). This could be easily noticed by observing that the average and median values of edits per contributor did not coincide (112 vs. 37 buildings per user, respectively). The fact that most of the mappers performed few edits while few experts mapped a disproportionately large number of features is not only related specifically to our project. It is instead a widely known effect in the OSM environment (Coetzee and Rautenbach 2016; Brovelli et al. 2020) and, more generally, in many citizen science projects (Lintott et al. 2008; Dickinson and Bonney 2012; Curtis 2014; Sauermann and Franzoni 2015) (Figs. 6.15 and 6.16).

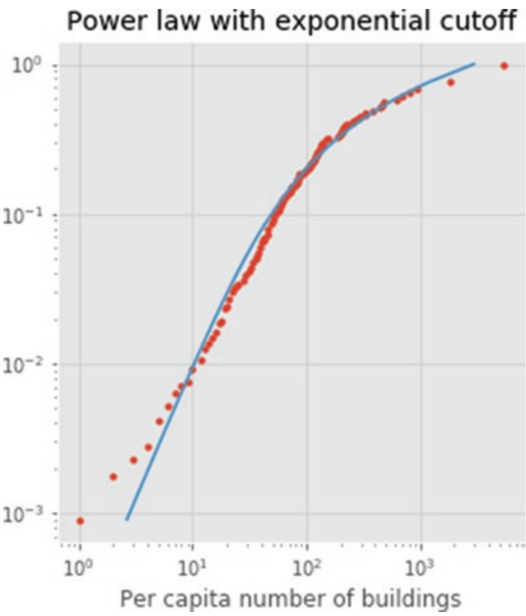

Fig. 6.14 Power law with exponential cutoff (in blue) fits the cumulative frequency to the per capita number of changes on OSM

4 Conclusions for Joint Youth Action on SDGs

This research project allowed us to advance the knowledge on the use of open collaborative mapping to fight a disease, in our case schistosomiasis. We created geographic information that permitted us to improve the habitat mapping of both the intermediate (snails) and the definitive (humans) hosts of schistosome parasites. As for the former, we collected and analyzed high-resolution multispectral drone imagery of aquatic vegetation spots; for the latter, we leveraged open participatory editing on OSM to improve or, in some cases, to start the mapping of the villages of the focal region of Saint-Louis.

The field mapping experience developed through this research project has been essential to gather drone imagery that can be used to feed eco-epidemiological models. Such geographically informed data can be important to refine the description of disease dynamics. Also, our data may be important to train supervised classifica-

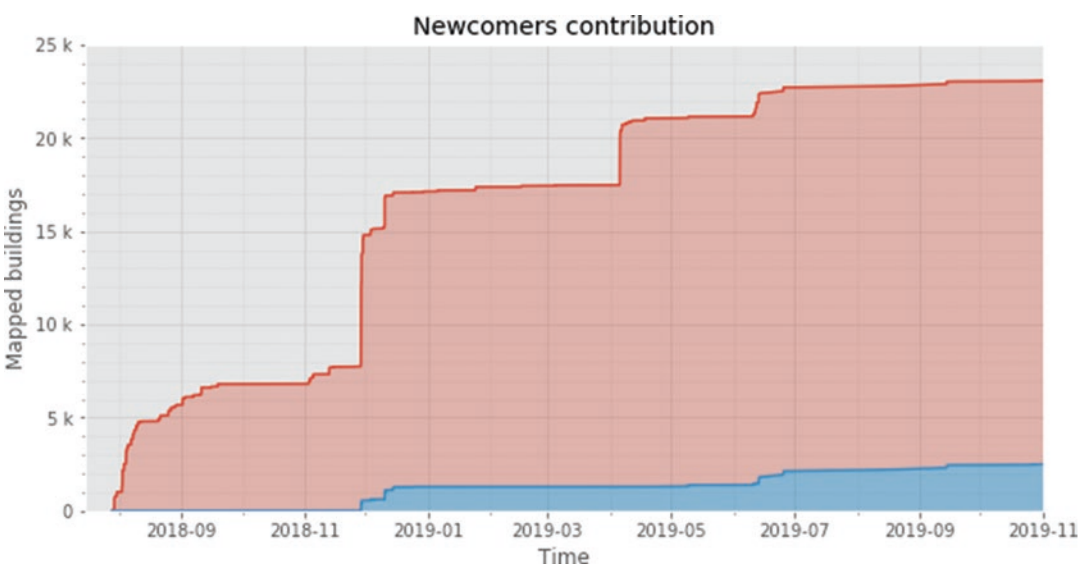

Fig. 6.15 Newcomers' share of total contributions began later in the project and remained a steady source of data

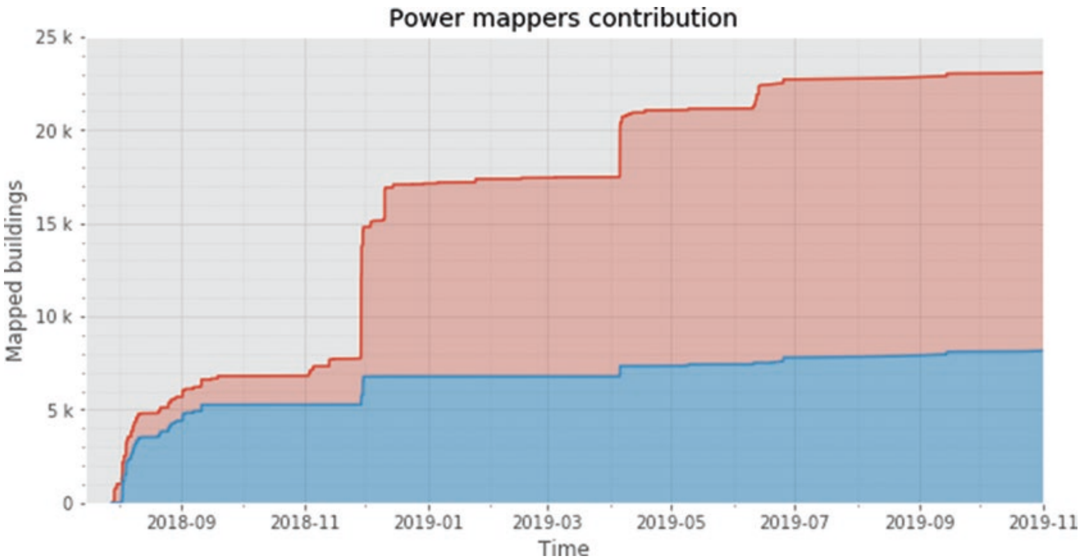

Fig. 6.16 Power mappers' share of total contributions were responsible for much of the early success and remained steady throughout the duration of the project

tion algorithms designed to perform large-scale mapping of spots of aquatic vegetation. What we also experienced in our project is that the engagement of local researchers, YouthMappers, and citizens proved to be key to performing field activities, not only in terms of logistics but also to overcome language and cultural barriers and to identify and access the best survey areas. The benefits of an expanded team were not limited to the advancement of the project's goals though. In fact, on one side, by involving contributors from the region of Saint-Louis, the project contributed to local capacity building; on the other, by involving international YouthMappers at their first field experience, it served as a crash course introduction to the reality of what mapping from the ground really entails, as compared to the most usual "armchair mapping" from the sky.

On the other hand, the open participatory mapping leveraged in this project was key to create geographical data on the human habitat in the Saint-Louis region of Senegal, allowing to put on a map vulnerable villages through collaborative editing activities. The project contributed to a significant increase of buildings mapped in Senegal (+9%), even more so in the Saint-Louis region (+33.6%). We went from 282,016 (Senegal) and 74,773 (Saint-Louis) buildings in OSM before our project to, respectively, 305,143 and 93,564 at the end of it. Even though the majority of our contributions came from gathering events, unsolicited contributions were also considerable. The presence of expert mappers in our meetings led to events with more contributions and longer retention times. The average number of edits per contributor typically followed a power-law distribution, meaning that most of the data were edited by just a few users. This confirms not only that retaining users in OSM may be difficult but also that "building mappers" is crucial for the long-term sustainability of open data and communities. Although most of the newcomers did not keep on mapping, they all contributed at least once to the generation of spatial information for the project and the wider OSM community, and are now aware of the power of open mapping. Conversely, the few newcomers who kept on contributing (around 10%) might hopefully become future long-term contributors and possibly introduce other newcomers to OSM. That is indeed what happened to the three youngest authors of this work: Michael, Fabio, and Ibrahima were all newcomers less than six years ago; nonetheless, they were capable of leading YouthMappers chapters and running an international mapping effort (Fig. 6.17).

Fig. 6.17 A joyful meeting unites UGB YouthMappers and PoliMappers at Université Gaston Berger in Saint-Louis, Senegal

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