3 Needs, Challenges, and Opportunities: A Review by Experts

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This section is an analysis of the needs and opportunities arising from international experts and managers in the field of Earth observation and publich health and the reference documents provided for this book. All the information collected has been grouped together into eight categories: (i) aligning with and supporting UN Sustainable Development Goals; (ii) focusing on public health needs and key theme areas for further research; (iii) accessing and developing Earth Observation (EO) and geospatial evidence-based data and products leveraging public health capacities; (iv) developing a sustainable community of practice; (v) developing knowledge and know-how; (vi) developing solutions: methods, tools, and systems; (vii) implementing technical infrastructures and technologies; and (viii) participating in EO satellite mission development for monitoring disease risks.

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Aligning with and Supporting UN Sustainable Development Goals

On the international stage, the United Nations Member States have adopted an action plan called *Agenda 2030 for Sustainable Development* that focuses on improving the lives of people and ending environmental degradation. The Agenda sets out 17 ambitious Sustainable Development Goals and 169 targets that integrate and promote transformative economic, social, and environmental activities of critical importance for humanity and the planet over the coming years.[2] Using remote sensing to aid public health aligns well with Sustainable Development Goal 3 (SDG 3), which aims to "ensure healthy lives and promote well-being for all at all ages." More specifically, EO and public health can offer promising support for Target 3D, which undertakes to "strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks." However, remote sensing can support the implementation of a number of SDGs that are synergistic with SDG 3. For example, better biodiversity conservation efforts under SDG 15 will ensure sustainable provisioning services for humans, ecosystems, and, therefore, the mitigation of the risks of zoonotic diseases, both of which contribute to SDG 3.

The Secretariat of the international Group on Earth Observations (GEO) has developed an umbrella initiative to support the SDGs in a comprehensive way. The *EO4SDG* initiative identifies specific SDG targets for which EO can contribute development and progress indicators. The Secretariat is also trying to better understand the interactions between different SDGs, to develop a focus on health, and to increase policy opportunities for geospatial data.[3] Their EO toolkit for sustainable cities and human settlements (SDG 1)[4] is the first of multiple toolkits planned for policy and decision makers, executive managers, and the interested public to encourage awareness of relevant EO applications and to facilitate collaboration with EO experts to meet Sustainable Development Goals and contribute to One Health solutions to public health concerns. The World Health Organization (WHO) promotes the development of a supporting framework and seeks to optimize the combined use of EO data, routine health information data, and other remote sensing data for advancing target-specific SDG 3 activities at national and subnational levels. However, national ownership, intersectoral collaboration, and having the technical infrastructure, a competent workforce, and adequate finances are essential prerequisites for the framework to function effectively with EO and other geospatial data.

Focusing on Public Health Needs and Key Theme Areas for Further Research

The emergence of diseases poses a great challenge for public health. An important element in facing this challenge is the necessity of predicting and targeting the location and time when the risk of disease and the factors leading to it pose a threat to human populations and where and when it will spread. Research and development, surveillance activities, and operational capabilities must constantly adapt and evolve in response to this growing threat, particularly regarding obtaining information on changes in climate, in the environment, and in human populations[5] that drive disease emergence and pandemics. With greater knowledge of drivers of disease emergence, public health organizations can better predict, anticipate, and detect risks, thus allowing preparedness of disease prevention, prioritization of surveillance efforts, and control actions to mitigate the risks of disease exposure or transmission. Methods that provide information on disease risks are numerous. Anticipatory methods include risk assessment by predictive modeling and forecasting, while emerging diseases and pathogens are identified in laboratory or field surveillance, which may occur proactively or in the face of outbreaks. Field data, supported by accurate laboratory diagnosis, are critical for the calibration and validation of models. This entails the collection of data on disease cases reported, socio-economic and demographic data, as well as environmental and climate data. In this context, EO data analysis becomes particularly useful as it supports the understanding and integration of disease emergence drivers as part of the modeling process. For example, by improving our understanding of wild animal vectors (such as bats) and their relationship with habitat features, we can use EO to monitor and model various climate and development scenarios to predict future areas vulnerable to zoonotic disease outbreaks.

Several research themes were identified as important for public health and where EO has the highest potential of having its greatest effect. They include mosquito-borne diseases, tick-borne diseases, air-borne diseases (pollution and extreme heat), water-borne diseases, vulnerable human populations, and pandemics and major outbreaks such as COVID-19. In North America and in Europe there are several organizations and programs that support R&D and offer specific theme-related solutions. Examples include the following:

- In Canada, the National Microbiology Laboratory, Public Health Risk Science Division of Public Health Agency of Canada (PHAC) provides EO solutions, R&D products from spatial modeling, surveillance products, services for the Canadian public health community, and support to public health emergency centers.
- The Canadian Space Agency's Space Utilization Grant and Contribution programs support the Canadian government priorities by funding industry and academia for many thematic application areas, including public health.
- In the USA, NOAA's One Health program provides EO solutions to identify heat and health threats, air pollution, and other related topics.
- NOAA's International Research and Applications Project, IRAP, supports activities to link science and assessments to practical risk management challenges in regions where weather and climate affect US interests at home and abroad; IRAP priorities in 2018 included "Decision Support Research on Climate-Sensitive Health Risks."
- NASA's Health and Air Quality program supports the use of EO in air quality management and public health, with emphasis on infectious diseases and environmental health issues.
- In France, Centre National d'Études Spatiales' (CNES) programs support research laboratories in the field of tele-epidemiology.
- EcoHealth Alliance, based in New York City, researches, monitors, and predicts the emergence of new zoonotic diseases through *in situ* data collection and modeling of the relationships between habitat conversion, wildlife trade, human population patterns, and other key factors to predict and better understand the factors driving the emergence of pandemics.

Accessing and Developing EO and Geospatial Evidence-based Data and Products Leveraging Public Health Capacities

Access to timely and accurate geospatial data in support of effective evidence-based decision making is one of the challenges facing public health organizations. The emergence of diseases, which is influenced by drivers such as changes in human or animal behavior, the environment, or the climate, has significant geospatial dimensions (Fig. 3.1). Geospatial information is needed for the development of indicator and risk models related to: human ecology, including the distribution, abundance, vulnerability, and behavior of humans; land use, land cover, and land degradation; human, animal, and arthropod vector habitats and biodiversity; the role of certain animal species that can amplify the threat and spread of disease; and mechanisms that interconnect all of the above. Geographic aspects are also important in that certain drivers have different impacts on and significance for disease dynamics in different parts of the world. Location-specific data, then, are vital in addressing risk, and EO is a meaningful source for these data for all regions of the globe. Satellites provide data that are continuously archived and cover most of the Earth, including remote and hard-to-access regions. Using multitemporal EO data makes it possible to update the information as needed. Depending on the satellite and sensor system selected, daily, weekly, monthly, or seasonal EO-based updates can be provided.

In order to meet their EO data requirements and utilize the data effectively, public health organizations need to collaborate with space agencies and other organizations that provide access to EO missions and data streams. Several public and private organizations offer procedures for ordering new satellite imagery and retrieving archival data sets. Selection and access to data

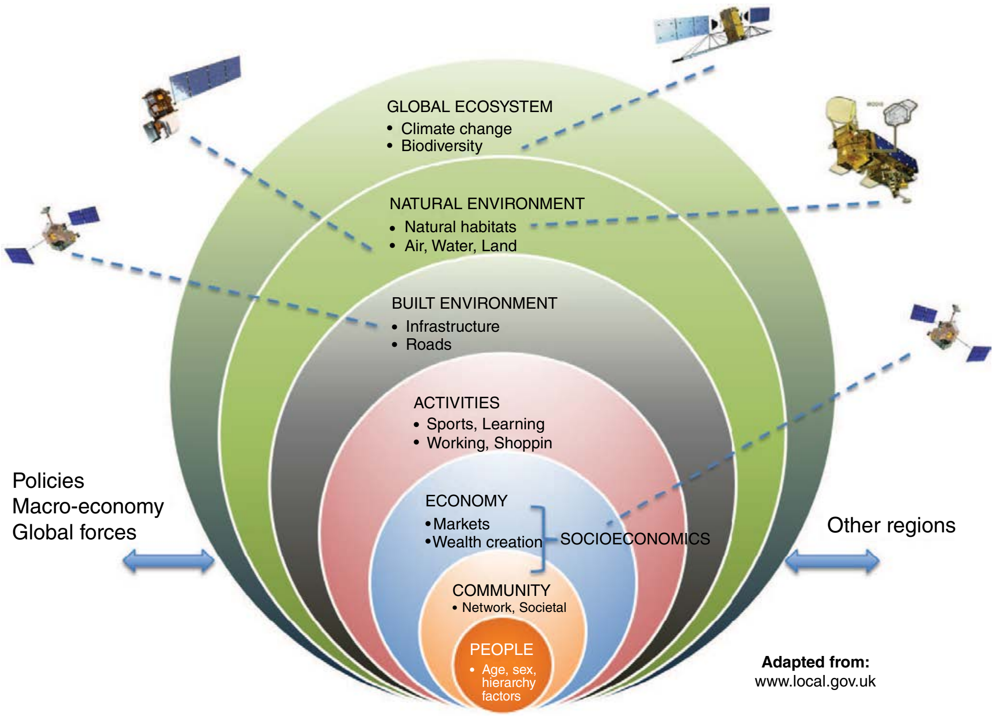

Fig. 3.1. EO and the multiple dimensions of health determinants.

and capacity to develop thematic information generated from those data can meet a substantial number of geospatial information needs for public health research activities. Near-real-time satellite data streams for generating up-to-date geospatial information are critical in addressing health-related emergency/emerging situations. Examples of high-resolution imagery for local and regional use include the Canadian RADARSAT constellation and the European series of Sentinel satellites under the Copernicus Programme; likewise, near real-time moderate-resolution data offered by US missions could satisfy information needs at the national or international scale. Additional EO data products (e.g. Global Forest Change data; Hansen *et al.*, 2013) can also prove useful for modeling disease emergence risk based on areas undergoing rapid land use change.

Optical and synthetic aperture radar (SAR) sensors at very high resolution are very useful for studies such as those investigating mosquito-borne diseases or COVID-19 disease within urban environments. In a research context, these types of studies are feasible but in an operational context, the cost and volume of such data could be prohibitive. Open access to EO data is critical. Sources for satellite-generated climate or environmental data that can be used to help assess the exposure of populations to a disease with environment and/or climate drivers are varied, some of which are freely available online.[6] A list of EO sources is included in Quattrochi *et al.* (2017) and in-operation open access EO images relevant for health determinants as well as advantages and limitations of the use of these images for health studies are included in Kotchi *et al.* (2019). Open data and data-sharing policies and promotion of participatory approaches to generating and accessing geospatial information are important prerequisites, as is the collection of health-related *in situ* data for producing spatial analyses.

Health studies and risk assessments rely on a variety of data sources (e.g. demographic, socio-economic, environmental) that must be integrated into models and health systems; providing reliable and consistent results remains essential. When dealing with health problems in different locations around the world, data sources can be heterogeneous in terms of content and quality. However, EO data obtained and used with appropriate analysis methods produce effective, homogeneous, and standardized information. Expanding and improving the accuracy of EO data will enhance model precision, sensitivity, and capacity to adapt to small changes in drivers that could influence the emergence of outbreaks.

The type of health issues and information needed will dictate public health decisions regarding the most appropriate resolution of EO images to use. Most mosquito-borne diseases require a high spatial resolution of ≤30 m to identify variations in the environment and climate used to support public health decision making. In addition, the availability of EO images makes it possible to develop risk and vulnerability maps at fine spatial and temporal resolutions. Water-borne disease risk modeling such as for *Vibrio* infections depends on EO images that support the modeling of sea surface temperature and sea surface salinity data. These data are available at low spatial resolution. The presence of *Vibrio* species in the water requires daily monitoring over time. EO data of greater spatial resolution could help refine these types of models. Air quality and heat wave modeling also uses the low-spatial-resolution data that are currently available, but high spatial resolution with frequent revisits is needed to better characterize urban pollution. COVID-19 has taught us how important data on inhabited environments are to assessing the effectiveness of public health measures and policies such as lockdowns or the links between the severity of symptoms and air quality. The availability of fine-resolution and timely images will also make it possible to make associations between the mobility of people and places at risk.

Local-scale risk prediction and surveillance are needed for differentiating objects or environmental changes in highly heterogeneous environments and for supporting local-level management. The timeliness of EO data is also an important factor because using these data in rapid risk assessment models or forecast models requires them to be both as recent as possible and ready to use. Downscaling approaches could provide the opportunity to obtain data with both high spatial and temporal resolution. They could involve multi-sensor data sets that integrate images of low spatial resolution and very high temporal resolution (daily) with multi-spectral images of high spatial resolution. Effective observation by air-borne and satellite-based optical sensors may at times be affected by clouds, pollution, and smoke, thus generating missing data and reducing the usefulness of EO products. Combining SAR and optical data offers some solutions to missing EO data due to atmospheric conditions.

Obtaining the desired data at all times and for all circumstances is often not possible. Although EO technologies are evolving rapidly, data useful for assessing a health event may be missing or may be obtained at unhelpful spatial or temporal resolutions. In coastal areas and in estuaries, the complexity of coastal waters makes it difficult to monitor water quality by EO satellite. This is the case for sea surface salinity data – currently available at a spatial resolution of 25 km – which affects coastal modeling of non-cholera *Vibrio* risk. Consequently, field instruments and modeling must make up for this lack of data. A multi-spectral or hyper-spectral sensor having the capacity to characterize surface salinity and surface temperature on a fine scale in coastal environments would be ideal.

In situ and epidemiological data

When studying a disease, combining geospatial data with other types of data such as *in situ* ecological, climate and weather, entomological, epidemiological, human demographic, socio-economic, and behavioral data is often necessary to calibrate models and validate their predictions. However, access to *in situ* data might be difficult because they are not always available, and the cost and time associated with collecting them is sometimes prohibitive.

In general, the more the better when it comes to accurate data on human cases and on presence, abundance, and persistence of microbes, arthropod vectors, relevant animal host populations, and human population characteristics. In low-income countries, researchers and public health practitioners depend on limited resources and often inadequate data on prevalence and incidence of the disease, including poor representation of the actual affected population (Programme National de Lutte contre le Paludisme, 2008; Diallo *et al*., 2012), as well as other ground-level relevant geospatial data (Section 2.5).

Interdisciplinary and inter-sectoral collaboration is needed to identify and prepare relevant EO products for public health applications. Once such products and their specifications are identified in collaboration with experts in land use, land cover, or infrastructure assessments, funding agencies have the opportunity to support the development of products related to the key public health themes outlined in this section and to foster collaboration among organizations. Now and in the future, EO technologies hold promise for detecting and capturing attributes of the Earth at increasing detail, which will support the development of tools and models that will provide better information on health threats.

Developing a Sustainable Community of Practice

The development of a strong and vibrant community of practice concerned with the use of EO for public health purposes is at the foundation for innovative action. This may take place domestically and internationally and result in improvements in how geospatial information is obtained, adopted, and managed for public health issues. Networking and collaboration also reinforce communication about health risks and vulnerability of populations, scientific discoveries, and emerging technologies. The participants in the One Earth – One Health workshop, held in Montreal in 2017, proposed several approaches to building and sustaining an active community of practice:

- Identify and articulate the needs of public health stakeholders and end users.
- Identify country-specific health-related activities that are addressed or could be addressed within the geospatial domain in the following dimensions: health technical areas, resource needs, and research agenda.
- Encourage interdisciplinary and inter-sectoral cooperation of public health organizations, space agencies, academic institutions, and industry under the One Health approach.
- Encourage international joint activities with GEO and WHO, encourage national space agency and public health institution initiatives and framework development, and address common public health needs.
- Support, design, and implement public health-related outreach activities involving EO and other geospatial data.
- Identify and implement national capacity-building opportunities that can strengthen spatial and temporal coverage of *in situ* data (e.g. in collaboration with Group on Earth Observations Biodiversity Observation Network [GEO BON]).
- Support and participate in the Convention on Biological Diversity (CBD), particularly with regard to implementation of the post-2020 Global Biodiversity Framework.
- Encourage formal cooperative agreements and activities among health and EO communities within government organizations, academia, and industry at the international and national level.
- Create opportunities for regular dialogue between EO experts and researchers, managers, and practitioners in the field, and encourage open access knowledge sharing; for example, the GEO Knowledge Hub is a cloud-based digital library (repository) that shows all the components of a given EO application required to reuse it.[7]
- Form scientific teams to study and report on specific topics, such as the formal Health and Air Quality Applied Science Team (HAQAST) supported by NASA.
- Support and participate in the volunteer effort of the GEO Health Community of Practice (CoP).[8]

Efficient interaction between the remote sensing, entomology, ecology/biology, epidemiology, animal health, environmental science, climatology/meteorology, social sciences, and public health communities is essential to informing a CoP that can integrate data from a wide variety of sources and at various scales and qualities. The provision of data and expertise by the large remote sensing community has the potential to provide data at a range of spatial and temporal resolutions that can support public health activities. EO products and methodologies will initially have to be custom designed to better fit public health needs, and proven methodologies need to be automated and more robust in the future – as well as user-friendly enough to be implemented by non-specialists.

While the technology can be further improved and more extensively employed, geospatial data producers within the Canadian federal community are well networked and already producing relevant information to inform public health mandates. For example, their *Ixodes scapularis* risk map (Section 2.2) provides reference data of the quality and relevance needed to feed predictive models of vector-borne disease and risk maps. Given globalization and the interconnectedness of the planet, expanding this CoP will benefit public health initiatives both at home and around the world.

Developing Knowledge and Know-how

The multi-disciplinary approach promoted by the One Health concept will help increase the knowledge and know-how of stakeholders to better identify and address the information requirements for critical health issues. Chief among them is a better understanding of how climate, environment, biodiversity, and socio-economics – including human–animal–environment interactions – affect the potential occurrence and emergence of diseases at various scale levels. There is also the need to improve prediction of diseases, detect emerging hotspots, and build early warning systems.

EO technologies and geomatics do, or could, satisfy many of these information requirements, and building the capacity for skilled human resources is essential for effectively utilizing EO data and deriving geospatial information from them. The following list includes proposed methods to stimulate the development of knowledge and know-how in the inter-related fields of EO and public health:

- Use government-assisted programs to develop know-how for the acquisition of EO data, the analysis of EO-derived information, and the integration with other geospatial data to support priority areas of research.
- Strengthen arrangements between public health laboratories and academic institutions focused on remote sensing, geomatics, geography, and other public health interests to develop highly qualified personnel and to support future research.
- Strengthen collaboration among space agencies and EO organizations and national and international public health agencies to widely share EO knowledge and best practices.
- Support the professional development and academic programs for a new generation of EO and health specialists (MSc, PhD) and R&D activities related to emerging fields such as big data analytics and deep and machine learning.
- Offer training through applied remote sensing training programs (e.g., NASA applied remote sensing training program [ARSET]), workshops that offer training on relevant EO and geomatics skills for end users, and long-term educational partnerships with communities and institutions in the public and private sectors.

Expertise in EO image analysis, geo-informatics, and mapping are prerequisites for the development of risk information products such as maps. There is a significant demand for assistance in the process of skills, knowledge, and technology transfer. This applies especially to the public health sectors of many countries that seek to employ effective geospatial assets to counter the threat of infectious diseases with the help of EO data analysis. Interagency cooperation to create new products that offer significant benefits to societal health is important. Health system improvements require dedicated resources for model development, EO data processing, and model forecast operations. In addition, skills and capacity among end users of integrated health and geospatial products are required to maximize their use.

Developing Solutions: Methods, Tools, and Systems

Public health organizations have been using the best available evidence and tools to advise and support national and international stakeholders in their work to enhance the health of their respective communities. However, more innovative scientific tools and methods need to be researched and promising solutions need to be implemented in public health programs to help combat increasing threats from infectious and chronic diseases. Hence, appropriate and interoperable EO-based products have to be specified, and spatial, analytical, and timely solutions need to be developed with the public health community. These could focus especially on epidemiological analyses, risk modeling, surveillance and investigation, and emergency management.

The EO-based information could support and improve public health decision making at many time scales, such as early warning forecasts for disease management of the most vulnerable areas and engaging in preparatory communications and planning for health administrators. Using EO data and tools, it could be possible to shift the current focus on responding to outbreaks toward predicting and preventing diseases.

Integrated health information systems offer solutions to address the current information gap between early warning and early action. The development of integrated methodological approaches from different fields of expertise using a wide range of relevant data to obtain public health risk maps serve to illustrate the complexity of public health issues. The French Space Agency (CNES) and its partners have developed a concept based on a deterministic/statistical approach of the climate–environment–health relationships adapted to what the space sector can offer; the approach is multi-disciplinary in that the study of the key mechanisms favoring emergence and propagation of infectious diseases brings together disciplines like environmental studies, climate science, social sciences, microbiology, entomology, and veterinary sciences.

In a similar way, GEO BON is fostering the development of an interoperable biodiversity observation system at national, regional, and global scales, and across terrestrial, marine, and aquatic systems. It integrates *in situ* and remotely sensed monitoring systems that bring together biodiversity, ecosystem conditions, and wildlife-related health observations. This system, in part, provides information on the change in biodiversity that could facilitate the emergence of infectious diseases and the exposure of vulnerable populations. GEO BON is working with the Open Geospatial Consortium[9] on interoperability across analysis-ready data (ARD) tools and services.

It is important to evaluate current systems that are intended to provide information about health risks in order to propose innovative ways to represent the level and spatial distribution of health risks. In this context, GEO's analysis of the resilience of the systems in place to inform health stakeholders would enable health and EO specialists to assess the capacity of the systems to perform this task. This evaluation of the systems would pinpoint both the weaknesses and the opportunities of the systems, both of which need to be considered when looking at how shocks and stresses affect systems and people. Depending on the solution, collaboration would help integration of health and environment data, different metrics, and reporting systems. While there is obviously a cost to this endeavor, the cloud offers a lot of opportunity around data infrastructure. In fact, GEO has 55 projects currently running with Amazon Web Services (AWS), Google Earth Engine, and Microsoft artificial intelligence (MS AI) for Earth.

Important EO systems include those provided by Copernicus,[10] Global Earth Observation System of Systems (GEOSS),[11] and Committee on Earth Observation Satellites (CEOS).[12] These systems could be assessed to measure how they could provide information on health risks and how they could support the integration of health systems. Health systems that could benefit from EO systems will have to be identified.

Artificial intelligence (AI) and Analyse ready data (ARD) solutions for complex issues

In an ever more complex world, where many different factors intersect to play dynamic and complex roles that affect the health and well-being of people, the ability to observe, measure, understand, assess, and take action on these determinants of health is becoming exponentially more complex. The methodologies for the production of risk maps developed by researchers of the EO community are not always suitable or adequate in a public health context for reasons that include the complexity of the methodologies, the cost of high-resolution data, and the lack of computing resources. Multi-temporal series of optical

EO data and the combination of optical and SAR data necessitate large data storage and analytics resources for regular production of risk maps. Also, the addition of new sensors (e.g. RADARSAT constellation, Surface Water Ocean Topography [SWOT], Biomass) increases the volume of EO data for their utilization while also compounding a data storage challenge. The development of adapted computing methods such as Artificial intelligence (AI) and machine learning algorithms with storage capacities will provide solutions that will need to be customized for public health purposes. The application of AI and related big data technologies could play a critical role in the enhanced application of EO to all the health-related activities discussed in this book (i.e. COVID-19). The potential benefits of applying AI and big data technologies to issues that influence health, safety, and well-being are, at this time, focused on critical zones where health priorities and this domain of innovative science and technology intersect.

The health community has identified the priority of increasing the capacity of public health officers to conduct rapid public health mapping and spatial analysis. To reach this goal, EO data management, a data cube, and a system that can provide Analysis ready data (ARD) for rapid modeling and timely risk mapping must be further developed. For example, Digital Earth Africa[13] offers continental water observations from space for free on an almost daily basis. Automated and generic methods are preferable to facilitate the production of EO-based products like land cover maps anywhere in the world. A high-performance computing system and cloud capacity will have to be studied to identify the best solution for big data storage and analytics and the best approach to produce health-related results. A large volume of data could be remotely processed and analyzed following the model proposed by Google Earth Engine – that is, without downloading data. Health communities would benefit from health systems that can process data with a secure interface, allowing the development of a sensitive and protected product. Public health and EO communities need to support research that would provide them with AI tools for big data analysis tailored to their needs.

Most EO data analysis and the production of risk maps require image processing time in expert software that can be done, in part, with geographic information system (GIS) software. Availability of freeware with EO and GIS tools, open access to EO data, as well as training programs strongly encourage the use of EO products. Future development should consider the implementation of tools through open-source software available internationally.

Implementing Technical Infrastructures and Technologies

The technical infrastructure for using EO data is a precondition of undertaking massive geospatial analyses to support public health-related decision making. Countries without this infrastructure depend on the infrastructure of other organizations to obtain EO data sets and to support their massive analyses. In some countries, the infrastructure to support big data analytics simply does not exist, or no formal agreement is in place to use existing infrastructure for EO and public health matters.

For those countries that currently have relevant infrastructure, the large volume of EO data streams and the high rate at which these require updating for disease risk assessment could rapidly exceed existing information management and information technology capacities and technologies. Producing and archiving data, products, and maps with high spatial resolution (≤30 m) for diseases that need this level of precision would require an exceptional data storage capacity. As the need for high-volume health-related data on environmental, climatic, and socio-economic factors has increased both domestically and internationally, the public health community is continuously challenged to maintain access to timely, reliable, and accurate EO data. Many health-related systems that integrate geospatial data already need big data infrastructure for storage and processing and sometimes 24/7 support for its operation, as is the case for AIRNow, FireWork systems, and the *Vibrio* map viewer (Chapter 2).

Updated and expanded IT infrastructure and software is a partial answer to the problems facing people responding to public health priorities and crisis. More effective and accurate mapping capacities support a variety of activities: risk assessments and decision making during health emergency events; risk communication via supplied images; and evaluation of factors affecting health via risk modeling. There is also a need for enhanced on-site information and the development of databases for the surveillance of diseases, so that greater effort can go toward the development of efficient EO-based models and tools to inform decision makers.

Participating in EO Satellite Mission Development for Monitoring Disease Risks

There are currently hundreds of EO satellites orbiting in space, and new missions are continually being planned for deployment. The usefulness of EO satellites depends in large part on the ability of users to access and apply the data and technology in practical settings to address their pressing issues. Satellite sensors are not primarily designed for health applications and often render spatial, temporal, or spectral data properties that are not of use for addressing public health issues. In Canada, the Canadian Space Agency has been building teams of remote sensing experts from different sectors, including public health. These users and science teams are integral parts of mission planning and utilization cycles, helping to identify observation requirements, specify technical needs, and develop instrument designs to meet a wide range of requirements and EO data needs. These teams can also participate in the calibration and validation of satellite data to ensure data quality.

Some EO satellite systems offer ARD (i.e. pre-processed images) and related information products derived from the raw data stream generated by the satellite instruments and the use of algorithms. For example, the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors onboard the US Aqua and Terra satellites offer atmosphere, land, cryosphere, and ocean products that are used in several user communities.[14] MODIS indicator data sets have been so successful that they do not require additional remote sensing analysis; they can be used directly in predictive models. Some missions have been influenced to produce data and algorithms specific to monitoring and managing health issues; for example, the NASA Earth Venture Instrument-3, which is a new Multi-Angle Imager for Aerosols (MAIA[15]). MAIA's mission objective with regard to health is to assess links between different air-borne particulate matter types and adverse birth outcomes, cardiovascular and respiratory disease, and premature deaths. Participation in mission development is an excellent networking and collaboration opportunity that will lead to important advancements in the field. One such advancement attributable to Landsat data is the ability to monitor changing patterns in forest cover loss and human encroachment on previously wild areas that allows for better prediction of zoonotic disease emergence.

Notes

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