Chapter 13
Geospatial Information Technology for Information Management and Dissemination

Sudip Pradhan, Birendra Bajracharya, Kiran Shakya, and Bikram Shakya

13.1 Introduction

Over the last few decades, the development of geospatial technologies has converged with a variety of formal information technology disciplines (Zwartjes 2018; Jackson and Schell 2009). The rapidly growing location-based services seamlessly integrate data and technologies from Earth observation (EO), Geographic Information System (GIS), Geographic Position System (GPS), and wireless and mobile communications (Huang et al. 2018). The emerging technologies for large-scale data storage, processing, and analytics and the increased availability and quality of the geospatial data have created unprecedented opportunities with broad implications for both technology and society (Liu et al. 2019). Today, we see the presence of various kinds of information systems in the Web, ranging from very basic data visualization to more advanced applications that do rigorous spatial analysis on the fly and present the results to the user over the Internet.

Looking back at the evolution of Geospatial Information Technology (GIT), the desktop GIS was prevalent in the world up until the early 2000s. Early Web mapping applications were mostly limited to simple interactive visualization of data as maps without much sophistication, and there were very few map servers available at the time, like Environmental Systems Research Institute (Esri) ArcIMS and Minnesota MapServer. Based on user requests, these servers generated maps in the form of images in formats such as Portable Network Graphics (PNG) and Joint Photographic Experts Group (JPEG) and sent them back to the Web browser for visualization of data. For each action on the user's part, such as zooming in or out, the map server generated new maps dynamically and sent the outputs to the user's browser. The servers back then were not powerful and could handle only limited

S. Pradhan (✉) · B. Bajracharya · K. Shakya · B. Shakya
International Centre for Integrated Mountain Development, Kathmandu, Nepal
e-mail: sudip.pradhan@icimod.org

B. Bajracharya et al. (eds.), *Earth Observation Science and Applications for Risk Reduction and Enhanced Resilience in Hindu Kush Himalaya Region*,
https://doi.org/10.1007/978-3-030-73569-2_13

map requests at a time. When the number of visitors using the map exceeded the server's handling capacity, it would slow down and, at times, crash.

All of this changed in 2005 with the arrival of Google Maps and Google Earth which gave everyone access to geographic information in a fairly democratic way. The ability to explore one's neighbourhood in 3D through high-resolution satellite images and navigation tools instigated spatial thinking in common people who did not have any technical background or specialized skills (Goodchild and Janelle 2010). Google Maps relied on serving pre-generated map tiles for each fixed zoom level instead of creating dynamic maps upon getting requests from the users; this optimized the map services and made them efficient. Google Maps also provided a number of base maps such as street map, satellite image, and terrain that acted as reference maps while allowing the users to overlay their own data on top of them. This became the industry standard and was adopted by many other agencies in the world. Today, there are several base maps available from different organizations such as Esri, Google, OpenStreetMap, MapBox, and Carto, and Web mapping applications are mostly built using base maps and overlaying the users' own data on top of them.

There has been a corresponding evolution on the application development front. Appropriate JavaScript application programming interfaces (APIs) such as Leaflet, OpenLayers, ArcGIS JavaScript API, and Google Maps JavaScript API have become available primarily to develop such Web mapping applications. In addition, there has been tremendous advancement in mapping servers as well in the past two decades. These days, server technologies such as ArcGIS Server and GeoServer are quite powerful. They are capable of serving a huge volume of data, carry out on-the-fly GIS operations, and are able to handle requests from numerous clients. Further, they support Open Geospatial Consortium (OGC) interoperability standards like Web Map Service (WMS), Web Feature Service (WFS), and Web Coverage Service (WCS), thereby enabling users to access data from different mapping servers and integrate them in their applications using the client software of their choice.

Another technological innovation of recent times is cloud computing which is becoming increasingly common and popular across the globe. The cloud offers high scalability in terms of processing and storage capacity with different modalities of payment that suit the users. There are numerous cloud-based applications and solutions that we use on a daily basis (e.g. Google Drive, Dropbox, and Microsoft 365). Esri's ArcGIS Online, which is popular among the GIS community, runs on Amazon Web Services (AWS) and provides a content management system that allows users to create and share maps, stories, and applications without writing any single line of code. Taking it forward, the advent of geospatial cloud computing platforms has brought paradigm shifts in the way we use GIS and remote sensing. A large number of satellites—fitted with various sensors—capture the data of our planet regularly, producing a huge volume of data at various geographic and temporal resolutions. A number of EO data such as MODIS, Landsat, Sentinel, and Global Precipitation Measurement (GPM) are freely available and have provided an opportunity to develop data products that are useful to decision-makers in various application areas. In traditional desktop-based remote sensing, individual scenes of satellite imagery are acquired, and specialized image processing software is used to generate the data products. As such, it would take a long time to produce data products that cover whole countries, and this would become much more complex when it comes to developing regional-level data products for multiple time periods. The geospatial cloud computing platforms such as GEE, Radiant Earth, and AWS, on the other hand, provide access to a huge collection of EO and geospatial data along with powerful computing facility to carry out image processing and analysis at the planetary scale. As an alternative to these platforms, the Open Data Cube (ODC) offers free and open-source solution for access, management, and analysis of a large collection of EO and geospatial gridded data.

There are increasing atmospheric and hydrologic applications using land-surface models which deal with data assimilation from various sources with complex and large range of spatial and temporal scales. There has been considerable progress in the development of data assimilation on continental surfaces in conjunction with the EO systems (Jean et al. 2016). Such applications are made possible by using high performance computing (HPC) clusters that consist of a collection of server machines connected together. In fact, HPCs are also implemented on the cloud using service from any of the key providers such as AWS, Google Cloud, and Microsoft Azure.

13.2 Adoption of GIT at SERVIR-HKH

SERVIR-HKH emphasizes the use of EO and geospatial technologies for environmental monitoring, food and water security, natural resources management to improve the resilience of the region to the impacts of climate change and other shocks and stresses. To achieve these overarching goals, it focuses on improved awareness of and access to geospatial data, products, and tools and increased provision of user-tailored geospatial services for informed decision-making in the HKH region. The evolution of technologies and their applications in the global context has influenced the way SERVIR-HKH is exploiting the opportunities of GIT to serve the region. The HKH region, like elsewhere in the globe, has seen a great improvement in Internet connectivity, with its presence becoming more and more ubiquitous, along with a significant increase in bandwidth and a sharp decline in price (Digital Nepal Framework 2019; ITU 2020). These factors have contributed greatly to making the Web the preferred platform for developing tools and applications. Although ICIMOD had been serving various GIS data and applications to partners through the Internet, including simple Web mapping applications for visualization since early 2000, the real journey of developing Web-based services began with the launching of SERVIR-HKH in 2010. SERVIR-HKH has been closely following the technological advancement and trends globally in the field of GIT. It has worked towards bringing the latest innovative tools and solutions to the HKH region by customizing them as per the local needs in ICIMOD's regional member countries. The options for platforms and technologies and the development approaches adopted for different GIT solutions are presented in the following sections.

13.3 Platforms and Technologies

The choice of platforms and technologies is generally guided by the desired functions, technological development, market trends, and available resources. Being the global leader, Esri technologies have been the primary choice since the introduction of GIS by ICIMOD in the early 1990s (Chap. 1). The technology options and platforms have been more diverse in recent years. The adoption of cloud computing is growing and increasingly becoming mainstream across the globe. Big data is another trend that allows analysis of extensive sets of information to generate the desired knowledge products. Besides, mobile devices have taken both the business world and the personal realm by storm, and the number of applications have skyrocketed in recent years. The key technologies and platforms that are used for developing applications and information services under SERVIR-HKH are presented here.

Esri's ArcGIS Technology: ICIMOD has been using Esri technologies as one of the core components of its geospatial infrastructure. The institution has implemented Enterprise GIS using the ArcGIS enterprise geo-database, and ArcGIS Desktop is the primary GIS client software used by its staff members. Most of the online mapping applications under SERVIR-HKH to date have been developed using ArcGIS JavaScript API, along with maps published through ArcGIS Server. Also, a number of data visualization applications and Story Maps have been developed using ArcGIS Online technology. Further, Esri's Survey123 for ArcGIS is used to build mobile field data collection for various services under SERVIR-HKH. Nepal Forest Fire Detection and Monitoring System, Land Cover Dynamics in Bhutan, and Glacier Dynamics in Afghanistan are some of the examples of the use of ArcGIS Server technology.

Google Earth Engine and Google App Engine: GEE is Google's cloud-based platform that enables environmental data analysis at the planetary scale. The GEE platform has been used by SERVIR-HKH to develop a number of applications such as annual land cover mapping for the entire HKH region and in-season crop mapping in selected countries. In addition, it is being used for big data analysis in various application areas. Further, a combination of GEE and Google App Engine has been used to develop Web mapping applications that allow users to do on-the-fly data analysis and present the results to the users; for example, the analysis of the normalized difference vegetation (NDVI) anomaly and wheat area mapping for Afghanistan.

GeoServer, PostGIS/PostgreSQL, and OpenLayers: The GeoServer is a popular open-source Web map server that allows to share, process, and edit geospatial data. It implements OGC interoperability standards such as WMS, WFS, and WCS. The PostGIS, on the other hand, is a spatial database extension for the PostgreSQL database, and the combination of these two provides open-source solutions for storing spatial data in the object relational database management system. As for OpenLayers, it is a JavaScript mapping library that enables consuming maps published from various Web map servers and putting together interactive Web mapping applications. The combination of these open-source technologies has been used to develop applications, especially when the applications are deployed at the partner's end and the use of commercial software is not feasible.

Tethys Platform: The Tethys platform consists of a suite of free and open-source software (FOSS) developed by Brigham Young University (BYU). It allows the development of Web applications using its Python Software Development Kit (SDK) and provides access to its core software components through the API. It uses Python Django as the Web application framework, along with GeoServer, for publishing data as map services, and PostGIS/PostgreSQL for storing spatial data. Further, it allows the use of OpenLayers for embedding dynamic maps in the Web applications. A number of applications under SERVIR-HKH have been built using the open-source Tethys platform. Some of the applications developed in the Tethys platform include the Regional Drought Monitoring and Outlook System for South Asia, Agriculture Drought Watch for Nepal, Bangladesh, and Afghanistan, and Streamflow Prediction for Nepal and Bangladesh.

Thematic Real-time Environmental Distributed Data Services (THREDDS) Data Server: The THREDDS Data Server is a Web server that provides metadata and access to scientific data sets. It integrates other open-source frameworks like the Open-source Project for a Network Data Access Protocol (OPeNDAP), OGC, WMS, WCS, and Hypertext Transfer Protocol (HTTP) to provide data access to its users. The THREDDS Data Server has been used to host many time-series data model runs like the High Impact Weather Assessment Toolkit (HIWAT), Routing Application for Parallel computation of Discharge (RAPID), and the South Asia Land Data Assimilation System (SALDAS).

SOCRATES: The HPC refers to the practice of aggregation of computing power that delivers much higher performance than one could get out of an individual desktop computer or workstation for solving large problems in science, engineering, or business systems (Sravanthi et al. 2014). The HPC can be achieved by creating a cluster that consists of a number of independent computers linked with the computation network; they act as a single computer which enables the processing of large data sets and solves complex computational problems at high speed using parallel processing techniques (Aydin and Bay 2009). The SERVIR Operational Cluster Resource for Applications—Terabytes for Earth Science (SOCRATES)—is an HPC cluster which has been established by SERVIR Global and is used by various SERVIR hubs as a shared resource. It is used to run the HIWAT system by SERVIR-HKH.

Amazon Web Services (AWS): Apart from on-premises servers, SERVIR-HKH also uses AWS to implement a number of online applications. For example, the Regional Drought Monitoring and Outlook System for South Asia and National Agricultural Drought Watch (Nepal) have been hosted on AWS.

Open Data Kit (ODK): ODK is a free and open-source software that allows rapid development and deployment of Android mobile-based data collection application. Along with Survey123, the ODK Collect has been used extensively for field data collections under SERVIR-HKH. For example, in the past, an ODK-based crop survey application was developed and used in collecting crop-related information in Nepal.

13.4 Development Approach

SERVIR-HKH follows a standard set of procedures when it comes to the development of services and related applications. Stakeholder consultation workshops and meetings are held to capture the requirements for each of the services in the countries where they are being built for. SERVIR-HKH uses the service planning approach wherein the users are placed at the centre at each stage of the design and development process (Chap. 2). The consideration of who the primary and secondary users are, what their needs are, and how the service will address those needs in terms of tackling issues on the ground is given utmost priority while designing and developing data products and applications. The tools and applications are designed and developed in close consultation with the primary users. Workshops and meetings are conducted to also capture the requirement regarding how the users will interact with the application. Regular meetings and exchanges are held with the primary users to gather their feedback at various stages of system development.

The institutional capacity of partners in terms of their existing IT infrastructure and technical skills are assessed to identify the gaps that need to be fulfilled to operationalize the services. The capacity building activities are embedded in the service development process such that the partners' technical capacity in terms of understanding and using the tools and information products of the services are built along with the development of the services.

Co-development is one of the key mantras of SERVIR-HKH, and wherever possible, it works jointly with its key partners in developing applications. For example, SERVIR-HKH and NASA's Applied Science Teams (ASTs) worked closely together to develop customized data and applications for various services such as Agriculture Drought Watch for Nepal and Streamflow Prediction for Nepal and Bangladesh. Together, they also regularly interfaced with key national agencies in generating and validating data products and developing customized applications to meet their requirements.

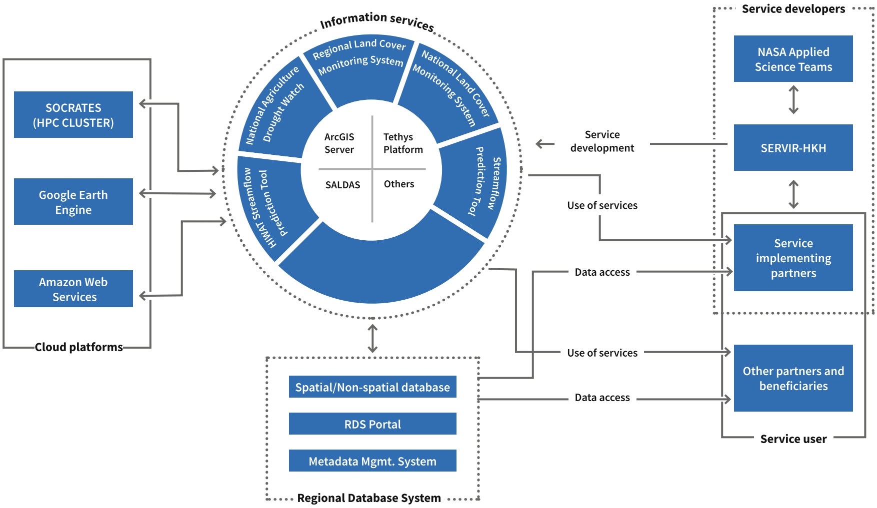


Fig. 13.1 Different components of SERVIR-HKH information services

SERVIR-HKH has also developed standard design templates for the front end of Web-based applications so that all the applications that are developed will have a similar look and feel irrespective of the technologies used at the back end. Nonetheless, the Web interface of the application is further customized in cases where the common standard template is not sufficient in providing tools, components, or user interactivity as per the requirement analysis. The different components of SERVIR-HKH information services are illustrated in Fig. 13.1.

13.5 GIT Solutions

The services of SERVIR-HKH are driven by the need for providing timely and right information to the right users in order to support informed decision-making. For this, the design of GIT solutions needs to consider the following key components:

- Data generation
- Data management
- Data dissemination (access and visualization)
- Application services.

13.5.1 Data Generation

The nature of services under SERVIR-HKH involves dealing with spatial data from various national and global data sets, including satellite images from different sensors and resolutions. Similarly, there are increasing data from field activities such as from forest and crop surveys, socio-economic surveys, and modelling activities which need to deal with model-specific input and output data. It is important to ensure that the data are collected and generated according to the industry standards for data consistency, quality, greater opportunity for data integration and aggregation, increased opportunities for sharing data, improved documentation and understanding of data and information resources, and data updating and security.

Various kinds of software and operational systems have been used to develop data products under different SERVIR-HKH services. The major data generation is carried out through the analysis of satellite images. In the first phase of SERVIR-HKH, the ERDAS Imagine and eCognition software were used primarily to develop data products such as land cover, glaciers and glacial lakes, and crop area. Aligning with the emerging trends, the GEE is being increasingly used in image analysis for applications such as developing the annual land cover data for the entire HKH region. Also, it is being used for big data analysis in various application areas under SERVIR-HKH.

Another set of data generation is from model runs such as SALDAS established at SERVIR-HKH. SALDAS is employed as the backbone of the Regional Drought Monitoring and Outlook System for South Asia and Agriculture Drought Watch for Nepal, Bangladesh, Pakistan, and Afghanistan. It is the implementation of the Global Land Data Assimilation System (GLDAS) developed by NASA for the South Asia region and provides, on a daily basis, the model run outputs for various drought indicator parameters such as precipitation, temperature, evapotranspiration, and soil moisture.

Similarly, HIWAT provides 48-h extreme weather predictions for lightning strikes, high-impact winds, thunderstorms, high rainfall rates, hail, and other weather events. It uses a mesoscale numerical weather prediction model and the GPM constellation of satellites. It is run during the pre-monsoon and monsoon seasons from April to September every year. The HIWAT system is implemented on SOCRATES, the HPC cluster at the SERVIR Global computing infrastructure.

13.5.2 Data Management

All the data generated under SERVIR-HKH are stored in ICIMOD's Regional Database System (RDS). The RDS is a central data repository for different thematic areas of the HKH region. A combination of ArcGIS enterprise geo-database and the Microsoft SQL Server is used to store spatial data, and the Microsoft SQL Server on its own to store non-spatial tabular data in the RDS. In addition, proper metadata is created and stored for all the data sets in GeoNetwork. GeoNetwork is an open-source metadata management system developed by the FAO. Depending upon the nature of the data, various metadata standards are used, such as the North American Profile (NAP) of the International Organization for Standardization (ISO) 19115-2003 for GIS and RS data, Global Biodiversity Information Facility (GBIF), Ecological Metadata Language (EML), Metadata profile for biodiversity data, and so on.

A backup strategy of incremental backup and a full backup plan is followed as per ICIMOD's IT guidelines to ensure safe and reliable data storage while also complying with the IT audit. Further, the Database Replica Server, a direct replica of a working database server, including both software and hardware, is implemented to ensure uninterrupted data services and to reduce the shutdown time of applications using these databases.

13.5.3 Data Dissemination

Data dissemination supports data discovery, access, exploration, visualization, and download functions. The RDS portal (https://rds.icimod.org)—a core component of the RDS—serves as ICIMOD's clearinghouse for data curation and dissemination and ensures easy access to the curated data sets which include those developed under SERVIR-HKH (Fig. 13.2). The portal provides free-text search and advanced search capabilities so that users can search by defining the title, abstract, keyword, or geographic extent. The search result would show a list of records consisting of the title, abstract, and thumbnail. The users can narrow down the search results using the provided filters and also view the detailed metadata of any record. Further, the users can download ICIMOD's published data sets after following a simple registration process. The portal offers specific tools to allow the download of temporal data (e.g. soil moisture or evapotranspiration) and climate projection data for a user-specified geographic area, time period, and other relevant parameters.

For the data which have been published as map service, the portal provides the facility to view the data as an interactive Web map using a Data Viewer application developed for the purpose.

All the data produced under SERVIR-HKH are publicly available on the RDS Portal for downloads. ICIMOD's Data Sharing Policy aligns with the philosophy of open and free access to scientific information and knowledge, and the data that are made available to the public by ICIMOD are licensed under Creative Commons Attribution (CC-BY) which allows the users to share and adapt the data as long as the creator is appropriately credited. In order to promote easier access to data on the Internet and also to facilitate proper citation, unique digital object identifiers (DOIs) are generated for the public data sets. A DOI is a persistent handle that identifies a particular data set uniquely on the internet (https://www.doi.org).

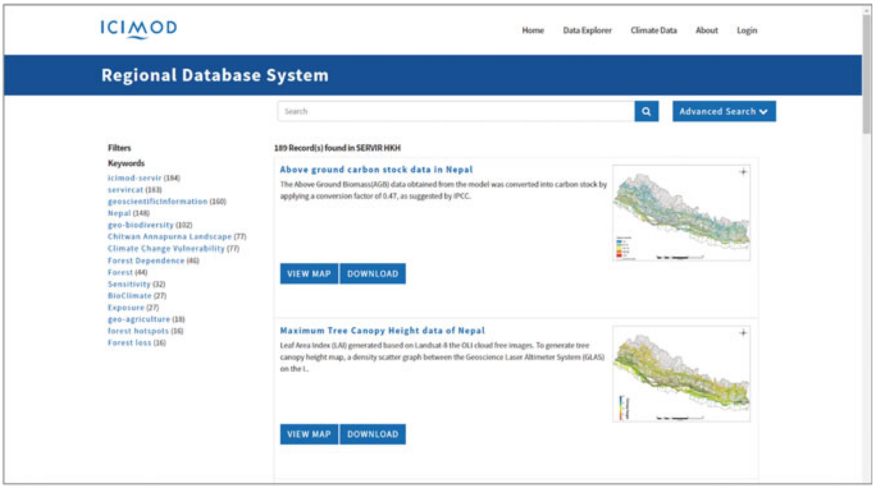


Fig. 13.2 SERVIR-HKH data on RDS

The data sets stored in the RDS can also be discovered through the Global Earth Observation System of Systems (GEOSS) GeoPortal (https://www.geoportal.org), DataCite (https://search.datacite.org), and Google Data Search (https://datasetsearch.research.google.com). And in the case of biodiversity data, they can be discovered through the Global Biodiversity Information Facility (https://www.gbif.org). Further, the data developed under SERVIR-HKH are also discoverable in the SERVIR Global Data Catalogue (https://www.servirglobal.net/#data\&maps).

13.5.4 Data and Information Portals

SERVIR-HKH has put conscious effort in transferring the developed information services to the relevant government agencies in ICIMOD's regional member countries. This helps in enhancing the sense of ownership over the information services among the agencies and also contributes to their sustainability in terms of operationalization and use. The capacity in the region varies greatly from one country to another when it comes to developing and maintaining information systems. As certain countries did not have the required IT infrastructure and technical capability in place, it was bound to be difficult to establish, implement, and maintain various applications at different agencies. SERVIR-HKH, therefore, worked towards developing a national geospatial portal that would act as a one-stop for data and information systems in those countries. Such portals serve as a platform for not only hosting data and information services developed under SERVIR-HKH, but also by different agencies in a country. This facilitates coordinated development and delivery of national geospatial services, thereby enabling improved decision-making and fostering collaboration among the various agencies in establishing effective policy for data standardization and sharing. Two portals, namely, Bhutan Geospatial Portal and Afghanistan Agriculture Information Portal, are examples of such efforts by SERVIR-HKH.

Box 1. Data and Information Portals

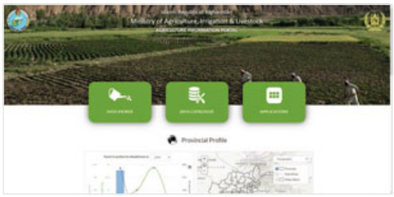
Bhutan Geospatial Portal

http://geo.gov.bt

The Bhutan Geospatial Portal has been developed jointly with Center for GIS Coordination and National Land Commission of Royal Government of Bhutan. The portal serves as a gateway to discover, access, and share geospatial data in Bhutan and allows development and hosting of interactive web based mapping applications that allow dynamic visualization and query of the data and generate information useful to various kinds of users.

Afghanistan Agriculture Information Portal

http://gis.mail.gov.af/afiims



The Afghanistan Agriculture Information Portal has been developed jointly with Ministry of Agriculture, Irrigation and Livestock, Afghanistan. The Portal facilitates the sharing of spatial and non-spatial data and allows integration of various web-based applications and provides tools to support informed decision-making in Afghanistan.

13.5.5 Application Services

The application services consist of online applications that provide query and visualization facility along with appropriate tools to generate information that is useful to decision-makers and the general public on various topics. The visualization of data in the form of maps and charts enables the users to understand the underlying issues better and helps them make informed decisions. User-friendly interfaces, along with the capability of interactive, intuitive, and innovative ways to explore and visualize data, are key aspects of the visualization component of the applications. Taking these into consideration, a number of Web mapping applications have been developed for various services of SERVIR-HKH. The individual applications can be accessed at https://servir.icimod.org/science-applications. Depending upon the features and level of complexities, the applications can be grouped into the following three categories:

- Simple visualization: The applications under this category enable simple visualization of data in the form of interactive maps (e.g. Flood Inundation Mapping, 2017).

- User interactive: Most of the applications developed under SERVIR-HKH fall into this category. The applications offer tools to query and visualize data in the form of interactive maps and charts based on user-selected parameters and geographic regions.
- Fully automated: These applications run on their own without any human intervention. They carry out tasks such as assimilation and processing of data, analysis and generation of statistics, and disseminating them through Web mapping applications in an automated manner (e.g. Nepal Forest Fire Detection and Monitoring System, Regional Drought Monitoring and Outlook System for South Asia, and Streamflow Prediction for Nepal).

As described earlier, standard Web design templates have been developed such that all the applications have a similar look and feel irrespective of the back-end and front-end technologies that have been used in developing those applications. The templates have been developed using Bootstrap, a front-end Web development framework, which ensures that the applications are responsive and are displayed well in variety of devices and screen sizes (e.g. desktop computers, tablets, etc.).

The applications consist of various common features such as map and chart sections for showing maps and charts. Likewise, a layer control section present in the application allows for the turning on/off map layers, while a tool control section lets the users to select parameters to view data and information in the form of maps or charts. Further, the applications also contain a section that provides brief information about the application and a link section that provides links to the relevant publication and to those for downloading data from ICIMOD's RDS portal. Finally, a feature to switch between English and the national language (e.g. Nepali) has been offered in a number of applications.

In addition to providing the facility to query and visualize data in the form of interactive maps through various online applications, SERVIR-HKH also allows direct access to data and map services to users with advanced technical capabilities. It also promotes the use of interoperable technologies and publishes its maps as OGC WMS services such that the users can readily integrate the data in their applications (e.g. https://bipad.gov.np). Further, SERVIR-HKH also provides the APIs used in the various applications to the partners on a request basis so that they can directly query the data in various SERVIR-HKH information systems and integrate the results in their applications.

13.5.6 Mobile Applications

The term "citizen science" was first used in 1969 and gained popularity in the 1990s (Haklay 2015). It is defined as "scientific work, for example collecting information, that is done by ordinary people without special qualifications, in order to help the work of scientists" (https://dictionary.cambridge.org/dictionary/english/citizen-science). A Web-based citizen science application was developed in the first phase of SERVIR-HKH to collect feedback on the land cover data of Nepal for 2010. The application allowed people to zoom to their familiar location or area and provide their feedback by selecting an option from a predefined list of land cover classes and also to type in their comments in the box provided. These days, mobile applications are predominantly used for field data collection as well as for getting feedback from the users.

A number of SERVIR-HKH services need field-based data either as training sample points that are required to develop data products or as data to validate and improve RS-based products. In this regard, a number of mobile applications for field data collections have been developed using Esri's Survey123 to support ongoing works of different services under SERVIR-HKH. A few of the examples of such applications include a Land Cover Survey App for Bangladesh and Nepal to collect sample points for validating the land cover data prepared in those countries under the National Land Cover Mapping System (NLCMS) and a Crop Survey App to collect various crop-related information such as on dominant winter crops, weather conditions, irrigation facilities, and cultivation status in order to support the Agriculture Drought Monitoring service in Nepal under SERVIR-HKH. The Land Cover Survey App is also planned to be used in the coming days to gather feedback from the citizens on the land cover data for the year 2019 for Nepal and Bangladesh.

Likewise, a mobile application for disseminating flood-related information has been developed jointly with Flood Forecasting and Warning Center (FFWC) of the Bangladesh Water Development Board, Bangladesh (Fig. 13.3). The application uses data from SERVIR-HKH's Streamflow Prediction along with other information products from the FFWC to provide forecast on the water levels at selected discharge stations in Bangladesh.

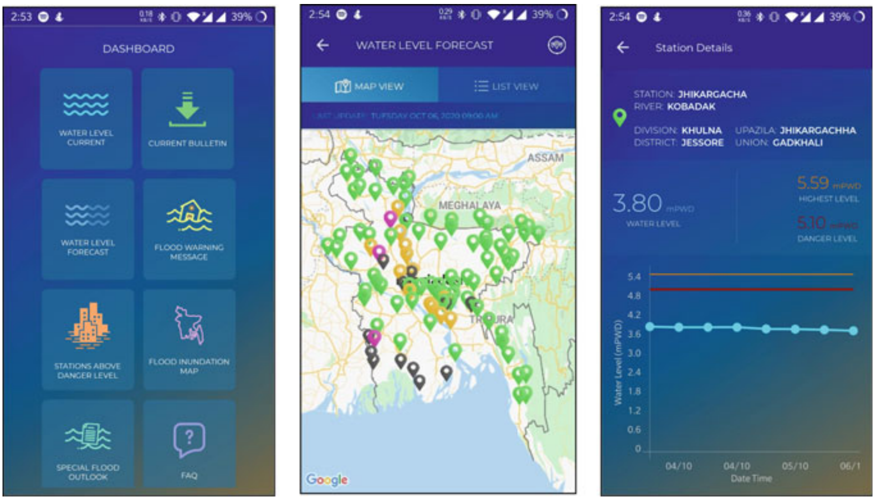


Fig. 13.3 Mobile application for disseminating flood-related information in Bangladesh

Table 13.1 Technologies and platforms used for GIT solutions at SERVIR-HKH

Functional group	Technologies and platforms	Data preparation	Data management	Data dissemination	Application services
Web-based map and data Publishing	ArcGIS Server			√	
	GeoServer			√	
	THREDDS Data Server			√	
Database management	ArcGIS Enterprise Geo-database with Microsoft SQL Server		√		
	PostGIS/ PostgreSQL		√		
Web mapping application development technologies	ArcGIS JavaScript API				√
	Open Layers				√
On-premise platforms	SALDAS	√			
	SOCRATES and HIWAT	√			
	Tethys Platform				√
Cloud-based platforms	ArcGIS Online				√
	Amazon Web Services				√
	Google App Engine				√
	Google Earth Engine	√			√
Mobile field data collection tools	Survey123 for ArcGIS	√			
	Open Data Kit	√			

The different technologies and platforms used for the purpose of data generation, management, dissemination, and application services are summarized in Table 13.1.

13.6 Experiences from SERVIR-HKH

Apart from spreading scientific knowledge, GIT plays a crucial role in developing innovative solutions using EO. GIT is a rapidly growing field where the evolution of technologies within a short span of time not only opens up new opportunities but also influences the efforts made on application development. The emergence of cloud-based platforms like GEE has enabled the development of applications to carry out big data analysis on the fly and present the results to the users quickly. There is an increasing trend of using artificial intelligence (AI) and machine learning algorithms in geospatial and EO applications. SERVIR-HKH has significantly enhanced the capacity of ICIMOD in terms of GIT infrastructure which has helped in making great strides towards implementing EO and geospatial solutions. ICIMOD has been making conscious efforts to train its human resources in these emerging fields and adopt them in various applications. This provides opportunities for executing more robust solutions that cater to the needs of the countries in the HKH region in the coming years. SERVIR-HKH has been providing regular trainings to staff from the partner institutions on the use of existing as well as emerging technologies which has helped in the co-development of applications and services. However, one of the major challenges is the limited capacity of the partners in terms of adequate GIT infrastructure; there is also the problem of frequent transfer of the staff who have been trained by SERVIR-HKH.

Regular monitoring and maintenance are necessary for the smooth operation of the applications and services. A number of fully automated systems developed by SERVIR-HKH rely on assimilation of data and on model outputs from global systems. In the event of a failure in data acquisition which happens a couple of times a year due to technical issues at the data provider's end, the operational system will not be able to generate information products.

One of the key considerations is the timely maintenance and upgrading of the hardware and software; this plays a crucial role keeping the applications operational. In some instances, the technologies used to develop applications change over time such that the existing applications need to be upgraded with the latest version of the software even during the development period. Also, certain applications need to be customized in order to add new functionalities as per requests from the partners. Further, the server hardware hosting the applications needs to be upgraded after certain years. Therefore, the provision of adequate financial as well as human resources is very important for the sustainability of the applications and services.

SERVIR-HKH has greatly benefitted from international collaborations in adopting the emerging technologies and keeping itself up to date with the global trends in the development of GIT applications. Co-development and close collaboration with AST projects have also provided the opportunity to develop the latest innovative data products and tools which are quite useful to partner agencies in their decision-making. Platforms such as SALDAS and Tethys were introduced through collaborations with the Applied Science projects. Similarly, partnerships with SERVIR-Mekong, the United States Forest Services (USFS), and Google helped in applications development using GEE. These collaborations were found to be a very useful learning process for all the institutions involved.

The main objective of SERVIR-HKH in developing applications and services is to enable the partners in using EO and geospatial information effectively. SERVIR-HKH has been making concerted efforts to ultimately transfer these applications to the partner organizations. A good understanding of the usefulness of the products and services has had a positive impact in terms of their adoption by the partners. The use of forest fire detection and monitoring system and streamflow predictions for flood early warning by national agencies in Nepal and Bangladesh are some of the examples. Further, the Bangladesh Meteorological Department (BMD) has initiated the process to establish the HIWAT system in the organization.

Our experiences show that while smart choices and use of technologies are key in designing innovative and effective applications to address the users' needs, the capacity building of partners and co-development are extremely important for adoption and sustainability of these applications and services. In this context, global networks and partnerships are indispensable to keep abreast of the latest technological advancements and to learn from each other, thereby building synergies among the GIT communities.

References

Aydin S, Bay, OB (2009) World conference on educational sciences 2009: building a high performance computing clusters to use in computing course applications. In: Procedia social and behavioral sciences, vol 1, pp 2396–2401

Digital Nepal Framework (2019) 2019 digital framework. Government of Nepal Ministry of Communication and Information Technology

Goodchild MF, Janelle DG (2010) Toward critical spatial thinking in the social sciences and humanities. GeoJournal 75(1):3–13. https://doi.org/10.1007/s10708-010-9340-3

Haklay M (2015) Citizen science and policy: a European perspective (PDF). Woodrow Wilson International Center for Scholars, p 11. Archived (PDF) from the original on 18 October 2016. Retrieved 3 June 2016

https://dictionary.cambridge.org/dictionary/english/citizen-science. Retrieved 20 September 2020

Huang H, Gartner G, Krisp JM, Raubal M, de Weghe NV (2018) Location based services: ongoing evolution and research agenda. J Location Based Serv 12(2):63–93. https://doi.org/10.1080/17489725.2018.1508763

ITU (2020) Individuals using Internet (% of Population)—South Asia, Nepal, Afghanistan, Bangladesh, Bhutan, Pakistan. World Telecommunication/ICT Indicators Database (database). https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=8S-AF-BD-BT-NP-PK. Retrieved 27 November 2020

Jackson, M, Schell, D (2009) The evolution of geospatial technology calls for changes in geospatial research, education and government management, directions magazine, April 7

Jean CC, Rosnay PD, Barbu AL, Boussetta S (2016) Satellite data assimilation: application to the water and carbon cycles. In: Baghdadi N, Zribi M (eds) Land surface remote sensing in continental hydrology. Elsevier and ISTE Press Ltd., Netherlands

Liu Z, Foresman T, van Genderen J, Wang L (2019) Understanding digital earth. In: Guo H, Goodchild MF, Annoni A (eds) Manual of digital earth. SpringerOpen, Berlin

Sravanthi G, Grace B, Kamakshamma V (2014) A review of high performance computing. IOSR J Comput Eng (IOSR-JCE) 16(1):36–43. e-ISSN: 2278-0661, ISSN: 2278-8727, Ver. VII

Zwartjes L (2018) Developing geospatial thinking learning lines in secondary education: the Gi learner project. Eur Geogr 9(4):138–151