Integrating Spatial Data Infrastructure in Monitoring Climate Change Impacts: A Research Oriented Approach

Rishiraj DUTTA* and Susantha JAYASINGHE
Asian Disaster Preparedness Center, Bangkok-10400, Thailand
*** Corresponding Author: rishiraj@adpc.net**

Key words: Spatial Data Infrastructure (SDI), climate change, geographic data, data quality, approach

SUMMARY

With the growing concerns of global climate change and its impacts on the environment, the geospatial community has been working extensively in collecting and assessing voluminous amounts of datasets to monitor and evaluate the changing climate. However, in order to make such enormous amount of data readily available, it is important that spatial data infrastructure (SDI) play a crucial role in offering accessibility to such data and information to researchers who would be interested to monitor and assess the issues related to climate change and addressing concerns to keep the environment sustainable by limiting the impacts with proper adaptive measures being put in place. Therefore, this paper describes an implementation approach of linking SDI into climate databases with the aim of reducing costs of geographic data and improving data quality, making data more accessible to the users, while at the same time increasing the benefit of using available data. The approach tries to design an SDI capable of monitoring, detecting, and predicting climate change so as to enable effective decision making. It also ensures the best sharing and exchange between partners and stakeholders so that they are interactively connected to use the data efficiently and in a flexible manner.

Integrating Spatial Data Infrastructure in Monitoring Climate Change Impacts: A Research Oriented Approach

Rishiraj DUTTA* and Susantha JAYASINGHE
Asian Disaster Preparedness Center, Bangkok-10400, Thailand
*** Corresponding Author: rishiraj@adpc.net**

1. INTRODUCTION

The term Spatial Data Infrastructure is described in the SDI Cookbook (Nebert, 2004) as "the relevant base collection of technologies, policies and institutional arrangements that facilitate the availability of and access to spatial data". Quality is often regarded as one of the metadata labels that can be addressed by reporting it to the users. However, if users wish to combine multiple sources, quality has a major role. However, quality management of geographic information could naturally be assumed to play a more important role in the near future. Geographic information is also vital to make sound decisions at local, regional and global levels (Nebert, 2004). The purpose of having a Spatial Data Infrastructure (SDI) is to support information discovery, access to information and use of these information for decision making. The information can help decision makers to take decisions on crisis management, flood mitigation, environmental restoration, community landuse assessments and disaster recovery as well as many others.

The term Spatial Data Infrastructure (SDI) was first coined by United States National Research Council in 1993 to denote a framework of technologies, policies and institutional arrangements that together facilitate the creation, exchange and use of geospatial data as well as related information resources across an information sharing community (ESRI, 2010). Such a framework can be implemented to enable the sharing of geospatial information within an organization or more broadly for use at the national, regional or global level. SDI extends a GIS by ensuring geospatial data and standards are used to create authoritative datasets and policies that support it.

It is always a known fact that information is an expensive resource and it may not always be readily available, particularly, in the developing world. Therefore, many national, regional and international programs and projects are focusing on improving the access to available spatial data, promote its reuse, and ensure that additional investment in spatial information collection and management, results in an ever-growing readily available and useable pool of spatial information (Nebert, 2004).

GIS can offer a practical and relevant working environment for the integration, analysis and visualization of climate related data together with other spatial data sources (Dobesch et al., 2007). Geographical data plays a key role in meteorology and climatology. They are used for different analyses such as spatial interpolation and modeling which in each case the data are a factor that determine the spatial distribution of climate elements as well as visualizing the results of measurements or calculations used as a background image for other data respectively. Meteorological modeling takes advantage of climate data while climatic analyses are based on meteorological data and in both fields' geographic data contributes as a vital information.

For many years now, various institutions have been collecting data at various scales to conduct research and development, however, it is also seen that the same kind of data collection approach is also being followed in different places which increases not only the cost but also affects the consistency in information obtained from various sources. Therefore, in order to avoid such problems, the concept of spatial data infrastructure (SDI) has become useful. In this paper, an attempt has been made to recognize the need for Spatial Data Infrastructure (SDI), and its relevance towards linking it to climate databases for effective utilization for research and development as well as decision making. However, in order to understand SDI, we need to understand GIS technology as well as SDI technology.

1.1. What is GIS technology?

GIS is a world of digital data, online portals, web services and location services that enables access to information when and where needed. GIS has been used as an effective tool of good governing, better business and a healthy planet. It is a complete platform for working with geographic information. It illustrates cost savings from better efficiency, better decision making, improved communications and better record keeping (URL: ESRI).

1.2. What is SDI technology?

Spatial data provides the locations and shapes of geographic features with descriptions of each feature and differs from normal data with its volume and structure (Bank, 2004). Spatial datasets are interrelated and often very large. Unlike any other related to business queries that may only return a few records, spatial queries for generating maps are routinely run against many thousands of features. Spatial data usually comes from across an organization and increasingly from outside sources. Because spatial datasets are fundamentally distributed and dynamic, standards and interoperability have always been a fundamental part of spatial data.

There is widespread recognition that the data layers and tables in most GIS implementations come from multiple organizations. An organization typically develops some, but not all, of its own spatial data content. At least some of the layers will be from external sources. Thus, GIS data management, by its very nature, is distributed among many users (ESRI, 2003). GIS requires a distributed information system concept to manage and share spatial data. Because GIS users are interested for quality geographic information, there is a fundamental need for users to share their data. Presently, thousands of organizations worldwide invest billions of dollars annually automating and integrating map information for their focused GIS projects. Their need for up-to-date geographic information drives these efforts. Therefore, SDI has become an essential tool when it comes to information integration. It works with geographic information from many sources to support a broad range of applications. SDI can repurpose information for new applications that go beyond the data's original intent. For example, information compiled for land records management can be used for environmental applications, utilities, emergency response and many other applications. Spatial data management includes not only data collection but also data dissemination. Interoperability enables data sharing between organizations and across applications and industries, which results in the generation and sharing of more useful information.

2. IMPACTS OF CLIMATE CHANGE AND ROLE OF SDI

The development of climate change adaptation policies must be underpinned by a sound understanding of climate change risk (Schneider et al., 2009) As part of the Hyogo Framework for Action, governments have agreed to incorporate climate change adaptation into the risk reduction process. The development of policies and strategies for adapting to climate change requires information about the nature of the risks posed to society. The better the knowledge base available to assess these risks, the more informed the decisions about adaptation are likely to be. Although it is desirable to have a comprehensive database available, however, some decisions can be made without extensive information or can simply be made on an ad hoc basis in response to changes in temperature or increased severity of storms and so on. Moreover, some of the impacts of climate change may be very costly, such as increase in droughts or bush fires, or even irreversible processes such as accelerated droughts or bush fires and the irreversible effects of eroded coast lines or degraded marine habitats. It is very important that access to spatial data requires to be put in place through a network of systems which can form a platform for fundamental source of information for assessing the impacts of natural and man-made hazards and its impact on vulnerable communities. This kind of system can be an SDI at the regional or national scale which can provide reliable and publicly available datasets to end-users.

Decision Support Systems (DSS) that rely on Geospatial information have proliferated over the past few years and are increasingly embedded in the operations of Regional Governments (Wall, 2009). Regional demand for wide-ranging and accurate Geospatial data that can be quickly integrated with other socio-economic and demographic data sets has become a high priority for policy makers and the necessary datasets a pre-requisite for informed decision making. This places a premium on effective Geospatial data coordination, central data management, data warehousing and optimum data sharing of priceless information and costly resources. One of the most compelling reasons for the development of a coordinated approach is the need for timely, effective, relevant regional data-sets for disaster preparedness with respect to events caused by climate change. Therefore, developing a Regional Spatial Data Infrastructure (RSDI) can provide a framework to facilitate the coordinated exchange of spatial information amongst spatial data stakeholders within the spatial data community which can also be interlinked to a country specific National Spatial Data Infrastructure (NSDI). In terms of monitoring impacts due to climate change, SDI at regional and national level can provide a base or structure of practices and relationships among data producers and users that facilitates data sharing and use (Rajabifard et al., 2004). However, there are always challenges in designing, building, implementing, and maintaining a Regional or National Spatial Data Infrastructure as it requires various disciplines to be drawn into a common platform and conduct examination of a large number of factors and issues.

Therefore, a well-established SDI for monitoring climate change impacts should fulfill the following objectives such as increasing the availability, access, integration and sharing of geographic information and enable inter-operability of geo-spatially enabled computer systems.

3. SPATIAL DATA INFRASTRUCTURE (SDI) AND EMERGENCY MANAGEMENT

SDIs provide platform for collaborative initiatives between national, provincial/state, regional and local organizations to develop technical, institutional and management frameworks that seeks to promote open access and exchange of spatial datasets. Representation of local government in developing and participating in SDI initiatives to facilitate emergency planning and management is highly critical and challenging as they operate as the first line of defense in times of emergencies. Spatial information or lack of it plays a central role in combating emergencies and in preventing or reducing losses. The critical hazard and disaster related information used, accessed and transmitted by different stakeholders involved in the emergency management process is crucial. Most often various organizations are required to put a joint effort for fighting the same disaster which essentially requires sharing common spatial databases, critical infrastructure information and often tapping into the common organizational and technical resources. SDIs built to support the needs and requirements of emergency management agencies would greatly enhance their capabilities in facilitating Emergency Planning and Management (EPM) in a multi-agency, multi-stakeholder environment. SDIs provide common platforms to develop policies, institutional arrangement and technologies that facilitate communities, organizations and decision makers at all levels of government to access, use and share geographic information for decision making process. Emergency and disaster response requires availability, access and unrestrictive flow of spatial data and services for which the roles and responsibilities of SDI is very critical.

3.1. Role of SDIs in Emergency Planning and Management (EPM)

EPM is an area where multiple agencies from all levels of governance have to work together to mitigate and combat emergency situations (Anand and Feick, 2009). No single agency has all the information that is required by the emergency professionals. Any emergency situations requires current and accurate location based data and information from different agencies and often from several different departments within one agency. This situation necessitates building partnerships and collaborative data sharing procedures among the agencies. The SDIs hold strong potential in building and facilitating these coalitions that foster open and easy exchange of geospatial information between multiple partners by improving on one hand, the availability and use of spatial data with standards, policies and procedures and on the other hand, facilitating effective decision making process in a time sensitive environment during emergencies. SDIs provide benefits that have wider implications for the emergency professionals and may prove to be extremely useful in all the stages of decision making in the emergency management cycle (Figure 1).

The data sharing principles of SDIs will allow large amounts of GIS data to be used by multiple organizations, rather than every single organization spending time, effort and money in developing and updating spatial information required by emergency responders (Soneren et al., 2007; Anand and Feick, 2009). It will not only open access of geographic information to the wider emergency management community but will also allow the establishment of standards and procedures for GIS data models and interoperability functions quintessential for emergency response and management operations (Rajabifard et al., 2004; Anand and Feick, 2009). Other benefits would include sharing of resources, personnel, technology, and facilitating partnerships between multiple agencies during emergency situations. The availability of multiple spatial databases and information from a single portal would provide overall assessment capabilities for emergency responders to assess the impact of disasters in a short time. It will improve their decision making capabilities and efficiencies for dealing with emergency preparedness, response and recovery. Sharing and exchange of spatial information will also help policy makers in contingency planning for emergencies and during the time of emergencies the SDIs facilitate the effective and timely communication of situational awareness not only to the emergency personnel but also to the wider community at risk (Soneren et. al, 2007; Anand and Feick, 2009).

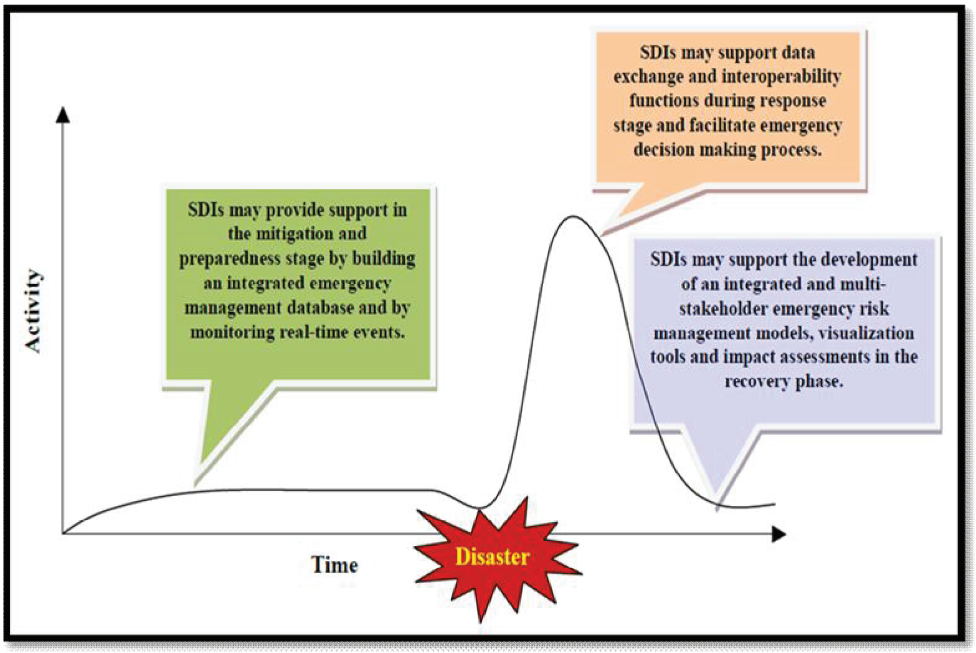

Figure 1: SDI and Emergency Management Cycle (Source: Anand and Feick, 2009)

4. KEY ELEMENTS OF A SPATIAL DATA INFRASTRUCTURE (SDI) FOR EMERGENCY OPERATIONS

Emergency response is directly proportional to human contribution which means for success of any emergency response mechanism, human contribution is a key factor. Not only that, access to quality data and information is another area of importance for a sustainable SDI. An effective SDI to a successful emergency operations, should have the following key elements (Steven, 2012) as described below:

4.1. Geo-data for SDI

An SDI should have a good geospatial database that includes actual geospatial data and information collected, processed, archived and distributed by various agencies and organizations. the databased should consists of actual geospatial data and information collected, processed, archived and potentially distributed by multiple agencies/organizations to meet disparate mission needs. It can also be property ownership, political boundaries, land use/land cover, transmission lines, transportation/energy grids, geology, soils, surface and groundwater hydrology, demography, disease vectors, economic service areas, and many more.

4.2. Metadata for SDI

With database increasing overtime, it is always important to document the data for future use by making it accessible to public as much as possible. Maintaining metadata with time to time updates helps organize and maintain an organization's data by avoiding duplication of effort by ensuring that the organization is aware of the existence of such datasets. It also enables users to locate all available geospatial and associated data relevant to an area of interest. It also allows potential users to compare similar data collected and held by multiple organizations in one sitting and make a studied opinion as to which data best fits the user's needs.

4.3. Framework

The base layers of data that most users agree is the base information that they will use to identify and describe the data using features, attributes, and attribute values. There should be mechanisms in place for regular updating of data without going for complete recollection. The framework should have provisions for continuous interactions among organizations for data collection and sharing.

4.4. Clearinghouse

A clearinghouse is based on a distributed network of people including the spatial data producers and users that are electronically connected with each other. The clearinghouse network enables the users to obtain the information about the spatial data availability, data requirements and how to access to it. The user can determine where spatial data are available and the quality and type of data.

4.5. Setting Standards

In order to maintain the reliability and accuracy of data made available to the public, certain amount of standards needs to be followed. The standards maybe created and accepted locally, nationally, regionally and globally. It is also recommended that ISO standards are followed that would give proper recognition to the data in terms of quality. The user can search the clearinghouse for spatial data with different mechanisms such as, the user can either use the predefined cases or search based on the location, key words or even based on the time of the data provision. The most popular mechanisms that a user can use are through predefined cases and key words.

4.6. Partnership

For effective and efficient functioning of an SDI, partnership with different stakeholders is important. This should enable the SDI to:

- Identify policy barriers and recommend practices and policies to overcome any such barriers;
- Reach agreement as to who would be the best data stewards for the principal datasets;
- Promote data sharing;
- Reduce duplication and;
- Extend local/national/global capabilities in technology, skills and sharing.

5. PURPOSE OF HAVING AN SDI

Without common standards and interoperable practices, many of the emergency services, relief ministries/departments, media, NGOs, academia, and private companies would have to generate their own views of affected area (s) to remediate the effects of any disaster and its aftermath. The goal of a National Spatial Data infrastructure (NSDI) is therefore, to allow these groups to communicate, collaborate and leverage disparate assets and specialists in real time with a maximum of efficiency and effectiveness.

6. SPATIAL DATA INFRASTRUCTURE FOR CLIMATOLOGICAL RESEARCH

One of the most important aspect of spatial data infrastructure is the sharing of spatial data in the internet domain. Some of these approach of data sharing can be used in the development of data infrastructure for climatological and meteorological research. Weather and climate data are spatial data that can be considered as GIS data, although their temporal component is still something most GISs have to deal with (Van der Wel, 2005). According to the Van der Wel (2005), a meteorological data infrastructure can benefit from experiences gained during the development of spatial data infrastructures and it is also possible to implement meteorological and climatological databases in these infrastructures.

It is always a known fact that any environmental issue requires decision making and monitoring tools to understand such issues thoroughly. For this to happen, proper accessibility to spatial data is important. Because these data are often stored at a number of institutes, at different levels of metadata, and comply with various data-handling policies, it is very much necessary that some national or international level infrastructure is needed to have easy access to such databases. One of the key examples of such infrastructure is the national spatial data infrastructure of United States of America developed in 1994. The structure focuses mainly on geospatial data, although there are clearly some atmospheric and climate 'nodes' in the infrastructure, such as NOAA's National Climatic Data Center. Another example is the Dutch National Clearinghouse Geo-information that helps provide uniform access to GIS datasets.

The INSPIRE[1] programme of Europe is a success story of a regional spatial data infrastructure. The main purpose of this programme is to improve the data accessibility by harmonizing geographical datasets that contribute to the definition of European Community policies. INSPIRE is based on a number of common principles:

- Data should be collected only once and kept where it can be maintained most effectively;

[1] http://inspire.ec.europa.eu/

- It should be possible to combine seamless spatial information from different sources across Europe and share it with many users and applications;
- It should be possible for information collected at one level/scale to be shared with all levels/scales; detailed for thorough investigations, general for strategic purposes;
- Geographic information needed for good governance at all levels should be readily and transparently available and;
- Easy to find what geographic information is available, how it can be used to meet a particular need, and under which conditions it can be acquired and used.

6.1. Climate Based Spatial Data Infrastructure (CSDI) for Nepal: A Web Based Approach

Open access to accurate and representative climate information has a huge impact on awareness raising, especially issues concerning with climate change and climate variability. Availability of climatic data is identified as one of the most important elements under the United Nations Framework Convention on Climate Change (UNFCCC) and its subsequent Kyoto Protocol to combat unprecedented climate change. In addition, access to a meteorological/climatological database via a web portal is essential for impacts and vulnerability assessments for climate change and climate variability in climate sensitive sectors such as agriculture and food security, water resources, biodiversity, health, etc., which is of utmost importance for sector specific policymakers, planners, stakeholders, end users and for the general public to plan their routing works.

The Nepal Climate Data Portal is designed to facilitate the analysis of historical climate/meteorological data as well as future climate scenarios in different geographical setting in the country using a publicly accessible web based interface. The portal was designed by the experts from the Asian Disaster Preparedness Center in Thailand through a joint venture programme with Bjerknes Centre for Climate Research (BCCR), Norway, in association with Department of Hydrology and Meteorology (DHM) Nepal, Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, The Netherlands, and The Energy and Resources Institute (TERI), India. It is a rather sophisticated calculator with its own meteorological database to produce maps, time-series charts or downloadable data. It uses a simple language to represent arithmetic and statistical operations like a spreadsheet. The project was implemented under the "Climate Data Digitization and Downscaling of Climate Change Projections in Nepal" funded by Asian Development Bank (ADB). The data portal is meant for research scientists, meteorologists, hydrologists, university students, sector specific decision makers and anyone who needs to understand past and future (projected) weather and climate patterns in the country. The portal also allows and facilitates the clients to purchase historical meteorological data that is regularly being collected by the Department of Hydrology and Meteorology (DHM) in Nepal over a several decades. However, understanding the vulnerability and impacts associated with climate change and climate variability in different climate sensitive sectors in different climatic zones is key for managing risks of weather and climate disasters and taking appropriate proactive adaptation measures for climate change. As the current degree of vulnerability and impacts to communities in Nepal and their resilience depend on physical, environmental, social and economic aspects, analysis of historical meteorological information on different temporal and spatial scales is of vital importance.

6.2. Structure and Design of the Web Portal

The portal was built in close alignment with the requirements for historical climate data and projected future climate scenarios. Sahana Eden Humanitarian Open Source Software platform has been used for developing the portal and Python 2.6, R, R multicore library, RPostgreSQL, rpy2, PIL, xvfb, PyQT4, QTWebKit were used to design it. The portal was designed in a way that it allows users to view the climate data on an interactive map and generate different information products including exporting the raw data (Figure 2).

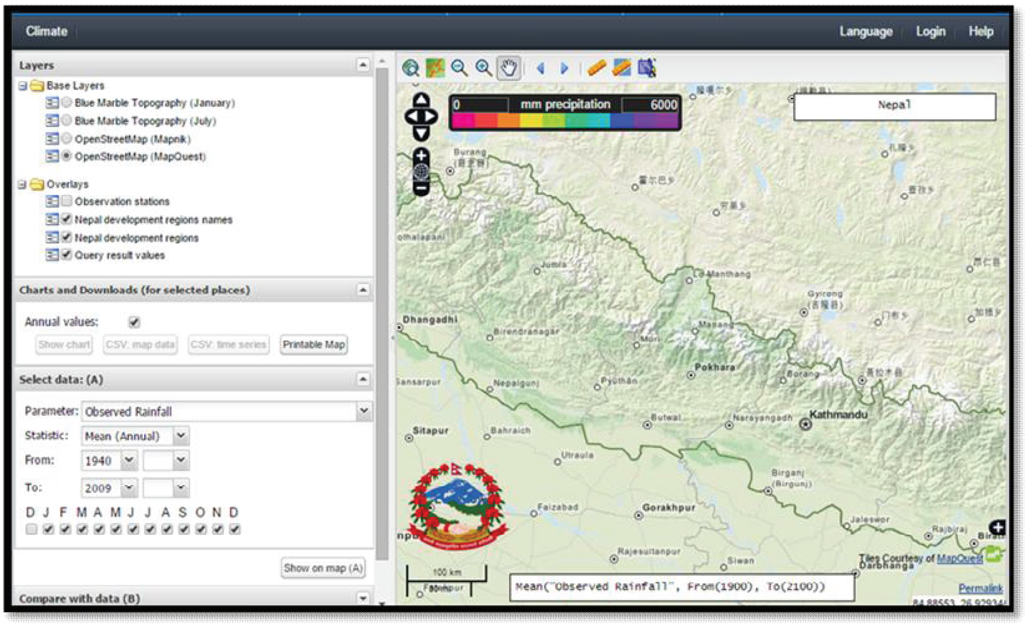

Figure 2: User friendly interface of Nepal Climate Data Portal

The portal provides various information products from observed gridded and projected climate data to cater the needs of different stakeholders (Figure 3). Technical experts and climate professionals prefer raw data for their own analysis while other professionals, such as government officials, policymakers and sector specific planners want analyzed end products such as maps and charts. The Nepal Climate Data Portal provides these data and information in a readily available format.

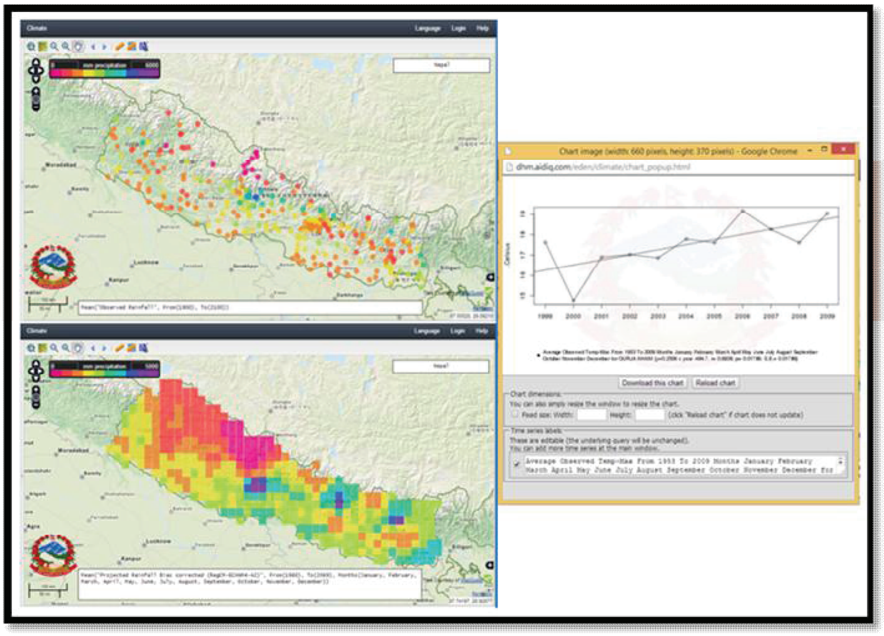

Figure 3: Maps visualizing gridded observed climatic variables (Monthly/Seasonal/Annual) and time series plots of modeled climate parameters (present-day and future scenarios)

6.2.1. Main Features of the Portal

The Nepal Climate Data Portal has the following features for providing better access to the historical meteorological/climatological data and future climate scenarios of the country as given below:

- It works as a sophisticated web-based calculating engine with its own database;
- It facilitates the analysis of climatological/meteorological, geographical and projection data using a publicly accessible web-based interface;
- It produces maps, time-series charts or downloadable CSV data;
- Its user interface allows additional climate data in netCDF format to be uploaded into the Nepal Climate Data Portal;
- For raw observed meteorological/climatological time series data, it needs to be purchased where the information on pricing options are available as specified by the DHM (sole authority of pricing of historical data is with DHM. Users will be able to purchase data directly from the site. Payments could be made, Offline, to the DHM office or Bank. After the payment is received by DMH, the user will be authorized to download the purchased data)

6.2.2. Usability and Applicability of Nepal Climate Data Portal

Climate data has been extensively used to assess impacts of climate change and to identify degree of vulnerability due to climate change in climate sensitive sectors such as agriculture, water, energy, health, etc. Therefore researchers, scientists, academics, sector specific planers and policy makers will certainly be benefited with the Nepal Climate Data Portal for their routing works such as:

- Research and Developments;
- Assessing impacts and vulnerability in climate sensitive sectors such as agriculture, water resources, energy, health, etc.;
- Developing adaptation strategies for vulnerable sectors;
- Infrastructure planning as adaptation measures;
- Contingency planning.

7. CAN CLIMATE BASED SPATIAL DATA INFRASTRUCTURE (CSDI) BE LINKED WITH NATIONAL GEOGRAPHIC INFORMATION INFRASTRUCTURE PROJECT (NGIIP)?

It is a known fact that spatial data plays a significant role in delivering effective government services, informed decision makings and creating business opportunities. At the same time, the capacity to meet such user needs and to deliver services and tools within the spatial information community has gone far beyond the ability of single organizations (Rajabifard et al., 2005), especially when more value-added and integrated spatial data is required for more complex analysis. Therefore, sharing of spatial datasets and collecting and integrating spatial data from different sources is crucial. For instance, we are fully aware that CSDI and NGIIP exist in Nepal which are part of National Spatial Data Infrastructure (NSDI). However, both are being used as two different entity with CSDI as Nepal Climate Data Portal under Department of Hydrology & Meteorology and NGIIP under Survey Department, Ministry of Land Reform and Management. In order to link both these entity under one SDI platform, the lead agencies needs to focus on cooperative relationships. Among them the most important is data sharing and joint working (Figure 4). Data sharing needs to be made in a way that both agencies obtain access to each other's data although sharing of data involves more than simple data exchange. In order to facilitate the spatial data sharing, spatial stakeholders require dealing with many issues including the technical and non-technical aspects of data integration (Onsrud, 1995). So to develop a link between CSDI and NGIIP, the most appropriate way to accomplished this would be to integrate data into a common platform. Data integration (Figure 4) is a compelling reason for sharing data. Integrating data in a spatial system will increase its effectiveness and creates opportunities for wider benefits between the agencies and help maintain consistencies and avoid duplicity of information.

However, there will be challenges that needs to be overcome while linking the CSDI and NGIIP that may include restructuring heterogeneous spatial information resources from different data providers in an application-oriented and user-oriented way. This is to ensure reducing duplication of effort among agencies, improve quality and reduce costs related to spatial information, to make spatial data more accessible to the public, to increase the benefits of using available data, and to establish key partnership with different ministries and departments, neighbouring countries, cities, academic institutions and the private sector to increase data availability.

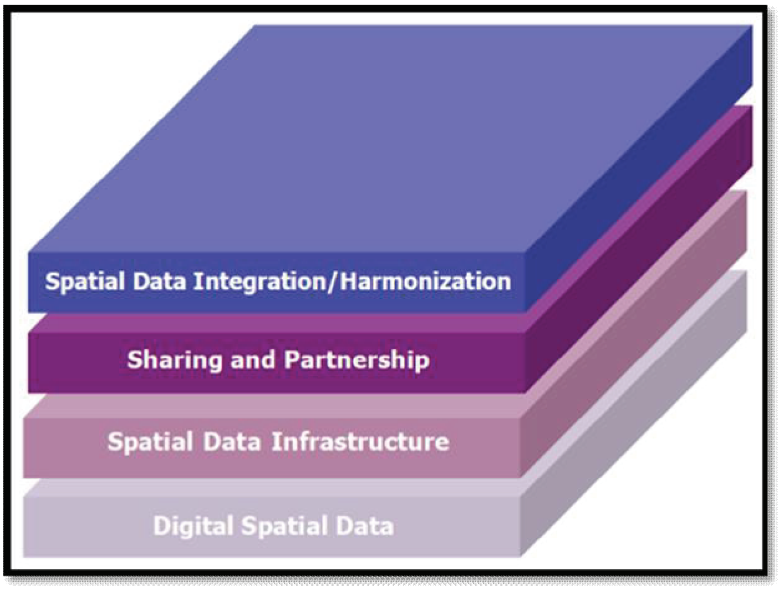

Figure 4: Spatial Data Management Continuum (after Muggenhuber, 2003)

8. DISCUSSIONS

The present portal is an indication that creating geospatial database is an important area that meets the needs of end-users not only for research oriented activities but also for decision making. Stakeholders were involved since the development of the portal till dissemination as much as possible, through various activities such as session to collect user needs during the inception workshop, online stakeholder survey conducted to collect specific needs and preferences for the design of the portal, consultative process with key stakeholders at Department of Hydrology and Meteorology (DHM) to garner their approval for the preliminary design of the portal, user testing with interested stakeholders for usability feedback, two consultation workshops on climate data portal to assess specific user needs and preferences through group discussions and questionnaires. Stakeholder consensus was also taken to further improve and finalize the design of the prototype version of climate data portal. This was to ensure that the system could serve the real needs of potential users. The final system was designed based on the feedback received from various stakeholders.

The entire study further showed that the sole purpose of SDI is not served if the integration of databases are not encouraged by the decision and policy makers as well as by the scientific community. According to Sharma and Acharya (2004), the aggregation and integration of fundamental data sets and framework data sets should solve the purpose of National Spatial Data Infrastructure (NSDI) for Nepal and should pave the way for easy accessibility of data md resources thereby making the works of user's community more simple, efficient and effective. Government of Nepal has already initiated the National Geographical Information Infrastructure Programme (NGIIP) for building NSDI since 2002 and therefore efforts should be made to integrate already available climate and geospatial databases including the CSDI to address the needs and concerns of the end-users. Not only is access to climate data and information needs to be linked or integrated within the SDI framework, so is the capacity of national institutions, leadership and civil society to determine what climate data and information is needed for adaptation-related decision-making (UNFCCC 2008). This will also address the fact that SDI in Nepal would be strengthened for planning and resource management through an integrated system of geospatial and climatological data infrastructure providing easy access to data for decision making. This can be further stated in the guiding policy statement on the importance of building an NSDI in Nepal and its probable links to make it operational as described under the NSDI framework.

9. CONCLUSIONS

Access to climate scenarios, historical climate data and information on climate change impacts will be a major asset to aid in development decision-making processes if it could be made to form part of a Spatial Data Infrastructure. Due to constraints in many countries including Nepal, climate information is either unavailable or inaccessible. Expertise in the application of climate data to decision-making is also limited. Therefore, to develop the capacity to incorporate climate change within development planning, a major component of SDI at the national level would be to strengthen evidence-based planning and decision-making by linking climate based information and resources to understanding climate risks, vulnerabilities and opportunities. This should be a way forward towards developing a climate base NSDI for Nepal which would allow decision and policy makers to take effective decisions in the event of any large scale natural disasters.

ACKNOWLEDGEMENT

The authors would like to acknowledge Asian Development Bank (ADB) for financial assistance to develop Nepal Climate Data Portal for DHM, Nepal. They also wish to thank Ms. Cindy Malvicini, Senior Water Resources Specialist, Environment, Natural Resources and Agriculture Division (SAER) of ADB for her valuable guidance in successfully completing the project on time. Also the authors would like to extend their gratitude to Ministry of Environment Science and Technology, Government of Nepal for granting the project on “Climate Data Digitization and Downscaling of Climate Change Projections in Nepal” in strengthening the capacity for managing climate change to the Department of Hydrology and Meteorology.

REFERENCES

Anand, A. and Feick, R. (2009). Spatial Database Infrastructure (SDIs) and Emergency Planning and Management: Challenges and Motivations for Local Government Organizations (LGOs). GSDI 11 World Conference, 15-19 June, 2009, Rotterdam, The Netherlands.

Bank, E. (2004). Importance of Open Spatial Data Infrastructure for Data Sharing. Commission TS-PS-WG IV/4, *ISPRS XXXV, 2004*.

Dobesch, H., Dumolard, P. and Dyras, Izabela (2007). Spatial Interpolation for Climate Data: The Use of GIS in Climatology and Meteorology. *British Library Cataloguing-in-Publication Data*, ISBN: 978-1-905209-70-5

ESRI (*URL*): http://www.esri.com/what-is-gis

ESRI Summer 2003. Standards and Interoperability

ESRI (2010). Spatial Data Infrastructure: A Collaborative Network

Harrold, W. (2009). Development of a Geospatial Framework to Implement a Regional Spatial Data Infrastructure (RSDI) in CARICOM. Ninth United Nations Regional Cartographic Conference for the Americas, New York, 10-14 August 2009.

Muggenhuber, G. (2003). Spatial Information for Sustainable Resource Management. International Federation of Surveyors, September 2003, 18.

Nebert, D.D., ed., 2004. *Developing Spatial Data Infrastructures: The SDI Cookbook*. Global Spatial Data Infrastructure Association, ver. 2.0, 25th January 2004, http://www.gsdi.org/docs2004/Cookbook/cookbookV2.0.pdf, (accessed, May 22nd 2007).

Onsrud, H. J. (1995). The Role of Law in Impeding and Facilitating the Sharing of Geographic Information. *In* Onsrud, H. J. & Rushton, G. (Eds.) Sharing Geographic Information. Rutgers: CUPR Press.

Rajabifard, A., and Williamson, I. (2004). Regional SDI development: A fundamental framework. *Journal of Geospatial Today*.

Rajabifard, A., Mansourian, A., Zoej, M. and Williamson, I. (2004). Developing Spatial Data Infrastructure to Facilitate Disaster Management. Proceedings from Geomatics 83 Conference, Tehran, Iran.

Rajabifard, A., Binns, A. and Williamson, I. (2005). Creating an Enabling Platform for the Delivery of Spatial Information. Proceedings of SSC 2005 Spatial Intelligence, Innovation and Praxis: The national biennial Conference of the Spatial Sciences Institute. Melbourne, Australia, Spatial Sciences Institute.

Schneider, J., Nadimpalli, K. and Cechet, B. (2009). The Role of Spatial Data in Understanding Climate Change Risk. Eighteenth United Nations Regional Cartographic Conference for Asia and the Pacific, Bangkok, 26-29 October 2009.

Sharma, R.K. and Acharya, B.R. (2004). Spatial Data Infrastructure for Prosperous Nepal. *Technical Session 2-Spatial Information Management Promoting Sustainable Development*, 3rd FIG Regional Conference, Jakarta, Indonesia; 3-7 October, 2004.

Snoeren, G., Zlatanova, S., Crompvoets, J. and Scholten, H. (2007). Spatial Data Infrastructure for Emergency Management: The View of the Users. In: Proceedings of the 3rd GiDM Conference, 22-25 July, 2007. Toronto, Ontario.

Steven, A.R. (2012). The US National Spatial Data Infrastructure: What is New? *ISPRS Workshop on Service Application of Spatial Data Infrastructure, XXXVI (4/WG6),* 14-16 October, 2012, Hangzhou, China.

UNFCCC (2007). Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. Available at unfccc.int/resource/docs/publications/impacts.pdf

Van der Wel, Frans J.M. (2005). Spatial Data Infrastructure for Meteorological and Climatic Data. *Meteorological Applications*, 12: pp. 7 – 8 (DOI: 10.1017/S1350482704001471).

BIOGRAPHICAL NOTES

Dr. Rishiraj Dutta works as a Technical Specialist (Climate Risk Management) in the Department of Climate Change and Climate Risk Management at Asian Disaster Preparedness Center (ADPC), Thailand. He has been working with ADPC since 2012 and has extensive knowledge and vast experience in Applied Remote Sensing and GIS. During his tenure at ADPC, he has served in various positions as Senior GIS Coordinator, Technical Officer (GIS) and Technical Officer (Climate Risk Management), and has been implementing programs and projects in the South and Southeast Asian region. He is also actively involved in project formulation, implementation and management within ADPC. Before joining ADPC, he worked with Consultative Group on International Agricultural Research (CGIAR) centers and served in various countries such as Colombia, Ethiopia, Kenya, India and Sri Lanka. Presently, he is also leading the team responsible for developing the Regional Drought Information System for the Lower Mekong region under the SERVIR-Mekong initiative, a NASA-USAID Global Program. He is also actively involved in areas focused on climate change, climate risk management, early warning systems, agriculture and agricultural sustainability, food security and has published several papers in reputed international journals. Dr. Dutta holds a Bachelor's Degree in Agriculture, a Master's Degree in Geo-informatics and a Ph.D. in Applied Geo-information and Earth Observation.

Mr. Susantha Jayasinghe's works is specialized in collecting and analyzing climate information at Asian Disaster Preparedness Center (ADPC), Thailand. In the department of Climate Change and Climate Risk Management, he analyzes the vulnerability and impacts in different sectors, generates and prepares advance warnings, and develops adaptation strategies and identification of risk management opportunities to address residual risk. Previously, Susantha has worked at the Department of Meteorology in Sri Lanka as a Research Assistant while at the same time attending graduate school in Geographical Information System (GIS) and Remote Sensing at the University of Peradeniya, Sri Lanka. He joined ADPC in 2010. Susantha holds a Bachelor's Degree in physical science.

CONTACTS

Dr. Rishiraj Dutta
Asian Disaster Preparedness Center
SM Tower, 24th Floor, 979/69 Paholyothin Road, Samsen Nai, Phayathai
Bangkok
THAILAND
Tel. +66 (0) 2298 0681-92
Fax +66 (0) 2298 0012
Email: rishiraj@adpc.net
Web site: http://www.adpc.net/igo/Default.asp