

BUILDING SPATIAL DATA INFRASTRUCTURE TO SUPPORT SUSTAINABLE CATCHMENT MANAGEMENT

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Abstract

Catchment management is characterised by multiple stakeholders and multiple goals which cut across traditional as well as administrative boundaries. It requires an integrated management approach as different institutions and individuals work together towards sustainable catchment outcomes. Spatial data plays an important role in formulating many catchment decisions. An increasingly problematic issue for catchment decisions is the availability and access of spatial data. Although the spatial data may be available, they may not be useful due to different standards, content or scale. The importance of spatial data to solving multiple issues concerning catchment management creates a growing need to organise data across disciplines and organisations through the development of Spatial Data Infrastructures (SDI). Due to the increasing development of land and natural resources, the management of rights, restrictions and responsibilities between people and land is becoming an important issue under the catchment management domain. This paper discusses SDI and its importance to catchment management. The role of catchment management authorities is explored and where these groups fit within the SDI development. A case study in Banepa Municipality, Nepal is examined to understand how spatial data infrastructure can assist in catchment decision making and management.

Key words: SDI, Catchment management, Cadastre, Sustainable development, Land encroachment

Introduction

Catchment management issues are characterised by multiple stakeholders and multiple goals which cut across traditional as well as administrative boundaries. Although local government has the extensive local knowledge and experience in catchment management, an integrated management approach is required for different institutions and individuals to work together towards sustainable catchment outcomes. Effective institutional arrangements are needed to bring different organisations together for catchment management. Spatial data now plays an important role in formulating many catchment decisions. An increasingly problematic issue for catchment decisions is the availability and access of spatial data. Although the spatial data may be available, they may not be useful due to different standards, content or scale. Spatial data is now essential to solving a range of catchment management issues and increasingly needs access to data across disciplines and organisations through the development of Spatial Data Infrastructures (SDI).

SDI is fundamentally about facilitation and coordination of the exchange and sharing of spatial data between stakeholders in the spatial data community (Feeney *et al.* 2001). Current SDI initiatives focus on SDI development at different political-administrative levels ranging from local to state/provincial, national, regional and global levels as highlighted by (Chan & Williamson 1999), (Rajabifard & Williamson 2001) and a hierarchy concept has been applied for SDI development. The issue of catchment management does not follow the rules of administrative hierarchy. It has its own spatial extent and coverage. Therefore, there is a need to build SDI differently, with a particular understanding of the catchment management perspective. As catchment management issues are characterised by multiple stakeholders and multiple goals, there are many issues to be addressed under the catchment management domain. Due to the increasing development of land and natural resources, the management of rights, restrictions and responsibilities between people and land is becoming an important issue under this domain. The institutional arrangement is a core component for catchment management.

In this paper, the role of catchment management authorities is explored and where these groups fit within the SDI development has been defined. A case study in Banepa Municipality, Nepal is examined to understand how the spatial data infrastructure can assist in catchment decision making and management.

SDI and Catchment Management Authority

As catchment management issues are characterised by multiple stakeholders and multiple goals, the institutional arrangements are therefore very important for catchment management. According to (North 1990), institutions are defined as 'the humanly devised constraints that shape human interactions; the rule of the games and organizations are the players of the games. Later, (Feder & Feeney 1991) distinguished three basic categories of institutions, namely the constitutional order, institutional arrangements, and normative behavioural codes. The institution can refer to either an organization or to social practices that are regularly and continuously repeated, sanctioned and maintained by social

norms, and bring order and stability to society (Reeve *et al.* 2002). Particularly for catchment management perspectives, both formal as well as informal organizations could be referred as institutions.

Stakeholders can be listed and categorized in many ways. The most fundamental division between stakeholders is likely to be between those who affect (determine) a decision or action, and those affected by this decision or action (whether positively or negatively). These groups may be termed active and passive stakeholders. In the present study, stakeholders are analysed based on whether they are Spatial Data Producers (government organisations) or Spatial Data Users (government, private or public).

In developing countries, catchment management stakeholders can be categorized into the followings eight categories according to their roles, namely:

- Government organisations at local/district and national levels
- Non government organizations (NGOs)
- Private sector
- Community groups and user's council
- Aid/Development organizations
- Academia and scientific community
- Science and environmental community
- Land owners and civil society members

Government Organisations at local/district and national levels

Government, the major enabler, has to play the most important role for Catchment Management and building SDI. Aiming at transparency in governance and sympathetic with the "Right to Information" tenet, Government has to position policies and implement strategies at various levels. Government agencies will have to take the first step by enabling the SDI nodes to come into existence. Government will also be a major user of the SDI mainly for its multi-farious developmental activities and administration.

Non Government Organisations (NGOs)

NGOs, the outreach agencies, can be a major user community for ensuring that SDI reaches the different rungs of society and people access SDI as an important information service. NGOs will also be users of SDI for their community development programmes and societal development at the grass-root levels.

Private Sector

Private sector, the other major partner, will have a major role to play in contributing to the design, implementation and operations of SDI. Not only in contracts for implementing SDI and software development, the private sector will have to rise to the challenge of pooling resources" to make SDI operational.

Community Groups and User's Council

Community groups are the main users of SDI. Community groups might be formal or informal. They work according to the norms and value of the society and have the capacity to work crossing the administrative/political boundary. Traditional authorities, local clubs, indigenous communities, ethnic groups etc. are the community groups having cultural, religious and spiritual values linked with the land, water and the conservation of its natural resources. They have a wide range of skills, knowledge, and technology that can play a positive role in the country's sustainable development. Their traditional resource management systems have many lessons for the management of sustainable catchment management. They create awareness during building SDI.

Aid/Development Organizations

In developing countries, Aid/Development Organisations provide the funds for SDI development. With respect to catchment management, they create awareness and can work as a lobbying agent for environmental protection and sustainable development.

Academia and Scientific Community

Academia and research community provides the research and technology development backbone for SDI. Academia will also be major users of SDI for imparting their education and training programmes and undertaking scientific research programmes. They help to build capacity for catchment management.

Land Owners and Civil Society Members

Land owners will be a major user of SDI. They use SDI for access and use of spatial information for catchment decisions. Civil society members are the leader of their society. They create awareness for sustainable catchment management and work as watch dogs of any decision making process and its implementation.

Building SDI

The principal objective for developing SDI for any political/administrative level, as highlighted by (Rajabifard *et al.* 2001) is to achieve better outcomes for the level through improved economic, social and environmental decision-making. The role of SDI is to provide an environment in which all stakeholders, both users and producers, of spatial information can cooperate with each other in a cost-efficient and cost-effective way to better achieve organisational goals. SDIs have the potential to promote widespread use of the available spatial data sets, which are essential to optimize spatial technology support for decision-making processes (Feeney *et al.* 2001). In most of the literature ((McDougall 2006; Rajabifard & Williamson 2001), SDI components are defined as data, people, standards, access and technology, policy and institutional arrangement. In this research paper, the followings are considered the main SDI components.

Data Model and Standards

For sharing and exchange of spatial database, the data model plays an important role. Data model is required for access, sharing and managing various kinds of data and their relationships. There are various data modelling tools such as the Unified Modelling Language (UML), which is very much convenient for data modelling at a logical level. The data could be populated in a physical model using some proprietary software like ESRI's ArcGIS. Spatial data delivery and distribution systems can also be based on this model. When required to implement user requirements it is also necessary to understand the various system that are operating or being build in different organizations or jurisdictions.

Metadata

A major difficulty in the spatial data community is the lack of information to help prospective users to determine what data exists, the fitness of existing data for planned applications and the conditions for accessing existing data. Metadata, which is the data about data, helps users to discover the actual datasets they require. In particular, it is the SDI content and information availability which is important. By making metadata available through data catalogues and clearing houses, data producer organisations also achieve benefits. The SDI metadata evolves from the NSDI standard and as the digital spatial information is populated. As a part of building SDI, one of the critical steps is the development of a metadata standard is the development of metadata files.

Electronic Clearinghouse

The SDI Clearinghouse is the mechanism to provide access to the metadata and finally to the actual data sets. The clearinghouse has to have systems to authenticate data requests. Often, the requests for spatial data usually entail large volumes of data and download through networks may not be feasible. In such cases, the system should be able to generate media with the requested data for transmission by mail. The clearinghouse should also store information about the applications and availability of application specific modules that could be reused by other users. The clearinghouse should use the SDI search and access protocols engines to look for and discover data and information.

User Interface

The User Interface is the front-end interface for user queries as access of spatial information is one of the important components of SDI development. With regard to design of SDI much depends upon the level of penetration, user applications and services available on it. For a completely ubiquitous SDI, the penetration will have to reach public domain and the capabilities will include online access of information applications.

Theoretical Framework

The theoretical framework for this research work is the relationship between land/water and people through their rights, restriction and responsibility (3R) and people's role for sustainable development as shown in Figure 1. Building Land Information Systems (LIS) incorporates the land/water management tools such as tenure, value, use and development. The LIS could be one of the components which supports catchment decisions and helps the building of the SDI.

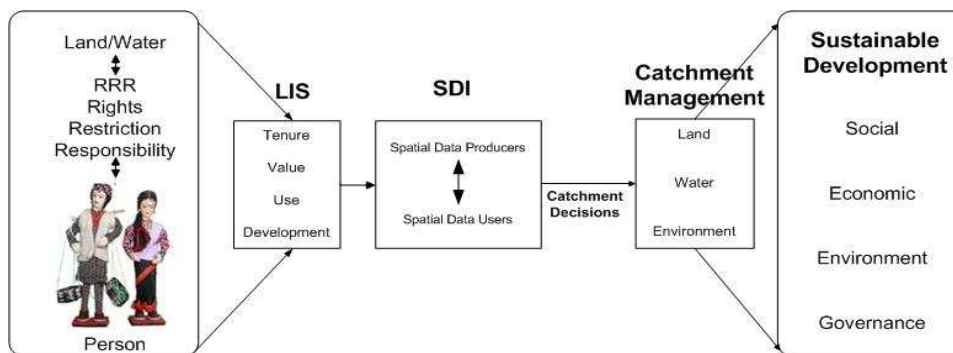


Figure 1: Link between SDI and Sustainable Catchment Management

In the SDI, there could broadly be two stakeholders; spatial data producers and spatial data users. As catchment management issues are characterised by multiple stakeholders and multiple goals; building SDI will assist catchment decisions and therefore promote sustainable development across the catchment and wider community. Sustainable development entails the effective incorporation of economic, social, political, conservation and resource management factors into decision-making (Ting & Williamson 2000). It therefore requires the resolution of many spatial decision problems in regard to managing the rights, restrictions and responsibilities between people and land/water.

Methods and Materials

In this paper, two approaches have been used for building spatial data infrastructure to support sustainable catchment management. Both the institutional as well as the technical aspects have been considered in this study. With respect to institutional arrangements, the roles and responsibilities of different stakeholders have been examined using an interest power matrix to assess how stakeholders may be best managed. The technical aspect of SDI is determined using spatial analysis tools. The digital cadastral information of Banepa Municipality has been taken as a base for building the SDI for catchment management. The integration of orthophoto maps, existing cadastral maps/land records and digital cadastral information are used to support catchment decisions. ESRI ArcGIS software and MS Visio is used for data modelling and spatial analysis.

Geographical Context

Nepal is a land locked country surrounded by China in North and India in South, East and West and endowed with rich natural and cultural diversity. The elevation ranges from 60m to 8848m, the highest peak of the world, Mount Everest. Geographically, it is located between 26 degrees N to 31 degrees N latitude and 80 degrees E to 88 degrees E longitude approximately. It has an area of 147181 sq km and a population of over 23 million. Population density of country is approximately 158 persons per square kilometre (CBS 2001). There are about 24 million of land parcels in the country with an average landholding per household of around one hectare. 70% of the households hold less than 1 hectare constituting only 30% of total agriculture land.

For administrative purpose the country is divided into 5 development regions, 14 zones and 75 districts. Each district is further divided into small administrative units called Village Development Committees (VDC) and Municipalities. There are 3914 VDCs and 58 Municipalities in the country (Paudyal 2005). Ecologically, Nepal can be divided into 3 regions: Mountain regions (above than 4870m), Hill regions (600-4870m) and Tarai regions (below than 600m). Of the total population of 23.15 million, 48.4 percent live in the Tarai, 44.3 percent in the hills and 7.3 percent in the mountains. The land resource mapping of the country has revealed that cultivated land covers about 20 percent of the total land, forest 29 percent, grassland 12 percent, shrub lands 11 percent, and other categories like rocks, snow lands and settlements make up the rest. Due to a wide variation in the topographical characteristics different climatic variations are available in Nepal (CBS 2006). Such a geographical setting of the country brings both complexity and opportunity for sustainable catchment management.

Study Area

The study area for this research is Banepa Municipality of Nepal which belongs to the catchment of Punyamata River (Figure 2). Punyamata River is one of the tributary of Sun Koshi River. The catchment of Punyamata River spreads over three Municipalities namely Banepa, Dhulikhel and Panauti of Kavrepalanchok District. For this study, Banepa Municipality is being investigated. The population of Banepa Municipality is about 16,000 people over a 530 hectare area. There are about 2500 households and 20,000 land parcels. Punyamata River originates from the hills and flows by the Banepa Municipality. Banepa Municipality is the northern gateway of Nepal which links Kathmandu valley with China as well as Eastern parts of Nepal. It is situated 25 km east from Kathmandu, the capital of Nepal. Being newly a developed city and near to the capital there is a rapidly growing population and high land values in these areas.

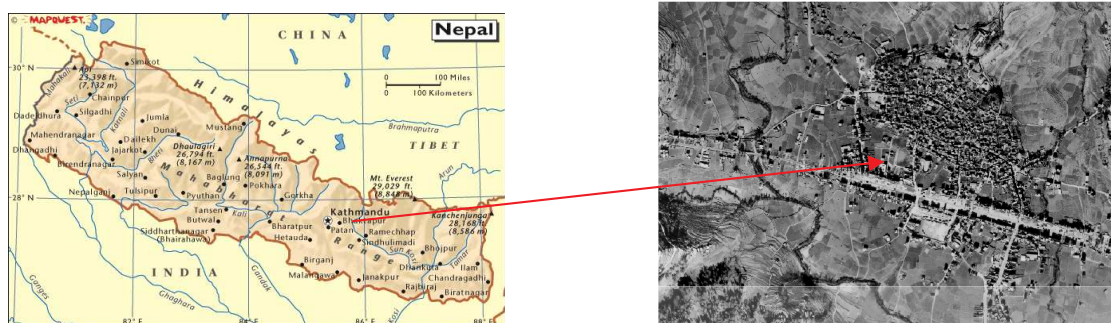


Figure 2: Location Map of Study Area

In the past, the natural flow of river was significant and people used the water for drinking as well as cleaning purposes. Now however, people and their activities have encroached on the river boundary for agriculture as well as residential purposes. In particular, housing companies have acquired land parcels near the river boundary to develop land. As the river parcel belongs to government, it is easy for Housing Companies and Real Estate Agents to encroach upon the river boundary by manipulating old and ambiguous cadastral data/land records. In some of the places, the course of the river has also been consistently changed by these housing companies and real estate agents. In this way, the capacity of the river has been reduced and shifted from its original course.

As a consequence, in the rainy season there are numerous problems with flood waters entering private properties and washing away the physical boundaries between land parcels. As a result, after the rainy season people need to redefine their parcel boundaries. There is also a tendency for land owners to over-utilise their land and encroach the river boundary. In addition, the cadastral and land registry documents which show the spatial extent of the parcel boundary are old and ambiguous and do not reflect the existing situation on the ground. Consequently, there are always boundary disputes between the Municipal Authority which manages the river parcel and land owners during boundary delineation of parcels which adjoin the river boundary.

Therefore, the catchment's management has become an important issue for the Municipal Authority. Considering these facts, the Government of Nepal has initiated a digital cadastre programme in Banepa Municipality to prepare a survey accurate digital database. One of the major objectives of the programme is to develop spatial data infrastructure at municipal level using the base of cadastral information. A systematic adjudication approach is used during data collection and the relationship (3R) between people and land/water is properly defined. The development of the cadastral database will be useful for many catchment decisions.

Stakeholders Analysis and Institutional Arrangements

In Nepal, Ministry of Land Reform and Management (MoLRM), Ministry of Local Development (MoLD), Ministry of Physical Planning and Works (MoPW), Ministry of Environment, Science and Technology (MoEST), Ministry of Agriculture (MoA), Ministry of Forests and Soil Conservation (MoFSC), Ministry of Water Resources (MoWR), Ministry of Health and Population (MoHP) are the main Ministries responsible for catchment management. Basically, Ministries are mandated to formulate and implement the policies and programmes for building SDI and Catchment Management.

Likewise, Planning Commission, Environment Division (MoEST), Science and Information Technology Promotion Division (MoEST), National Agriculture Research and Development Fund, National Commission for Sustainable Development (NCSA), Nepal Water Supply Corporation and various Departments under Ministries are also responsible to develop plans and programmes for catchment management. District level organisations like the Survey Office, Land Registration Office, Municipality, Utilities Services Organisations, Agriculture Office, Forest Office, NGO's and Community Organisations are responsible catchment management at the grass root level. Academia and scientific organisations are involved in capacity building and research activities. Therefore it is important that land owners and civil society take advantage of the capability of SDI and co-operate to facilitate sustainable catchment management.

In the current study, the stakeholders are classified on the basis of interest in SDI and the power or the influence they have in implementing the SDI for sustainable catchment management. The interest in SDI is extracted based on the following five criteria; namely:

- Degree of dependency
- Degree of interest
- Degree of influence
- Degree of impact
- Degree of adverseness

The power or the influence is determined based on the following questions.

- How significantly do the SI products and services affect them?
- What are their knowledge, expertise and information useful for SI products & services? (Form of participation).
- What are the responsibilities and powers related to SI products & services?
- What implementation powers and instruments do they control?
- What resources can they bring to SI products & services?

After determining the value for interest and power, an interest power matrix (deVries 2003) of the stakeholder's interest/power was plotted.

Spatial Analysis and Catchment Decisions

Spatial data plays an important role for catchment decisions. Decision-making may be broadly defined to include any choice or selection of alternative courses of action (Malczewski 1999) and is therefore of important to many fields in the social and natural sciences, including the geographical information sciences. A preliminary step toward achieving

decision-making for catchment management has been the increasing recognition of the role of SDI to generate knowledge, provide added value to identify problems, assist in proposing alternatives and defining a course of action. The relationship between people and land/water must be understood for catchments decisions. The Bathurst Declaration (UNFIG 1999) identified the need for reliable information infrastructures to record environmental, social and economic rights, restrictions and responsibilities as well as provide spatial data to facilitate appropriate decision-making. With this in mind, the land tenure rights, responsibility and restrictions for catchment management has been modelled using the case study of Banepa Municipality, Nepal.

Results and Discussions

The matrix of stakeholder’s power versus interest is illustrated in Figure 3. This matrix is used to position stakeholders according to their position of power and their interest in the issue at hand. Decision on stakeholder management can then be made as to whether the best approach may be for management may be to: A) keep stakeholders informed, B) manage stakeholders closely, C) keep stakeholders satisfied or D) only monitor the stakeholders.

A total of 66 organisations were analysed and mapped as shown in Figure 4. The major government agencies, environmental related organisations, community groups and local authorities fall within the “Manage Closely” grid. These organisations are the key stakeholders for building SDI and sustainable catchment organisation. The organisations like the Planning Commission, Ministry of Justice and Parliamentary Affairs, Ministry of Home, Ministry of Finance etc., and have high power, yet are not particularly interested in SDI but need to be “kept satisfied”. However, there is need for these organisations to increase there interest in spatial information. NGOs, Private Organisations, Academia, Aid Agency and a few governmental departments have minimum interest as well as little power for building SDI or catchment management. Therefore, these organisations need to be monitored with minimum effort. The rest of stakeholders, district government departments who have high interest, but less power need to be “Kept informed”.

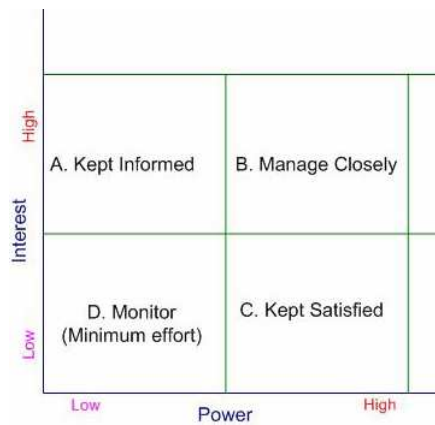


Figure 3 : Stakeholders’ Interest/Power Matrix (Adapted from (deVries 2003))

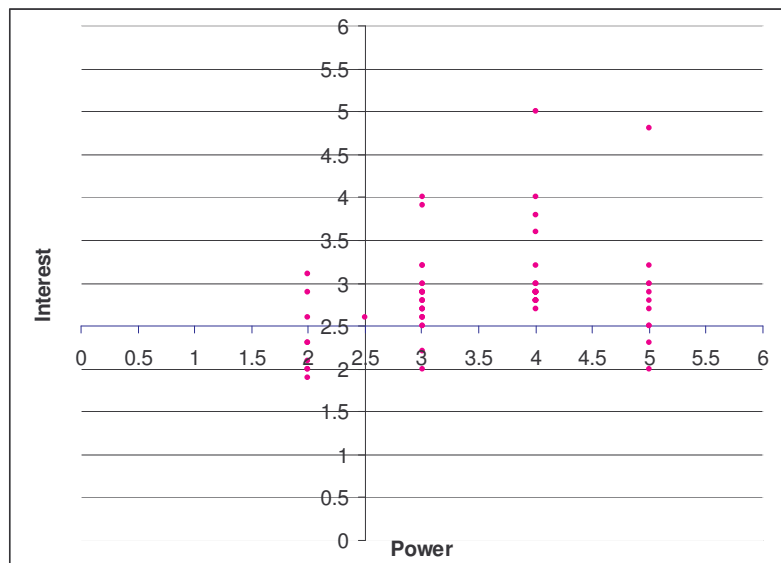


Figure 4: Stakeholders’ Mapping

Spatial Analysis case study

For the spatial analysis, a range of spatial data including digital cadastral data, orthophotos and existing land records were utilised. By using GIS to integrate the different spatial data, it was easy to convince land owners of the current situation and encroachments. Using spatial analysis, three decision problems were identified and modelled in the following case studies.

Case One: Encroachment in Rivers Bed

The encroachment upon rivers beds was identified by integrating existing cadastral data and the newly acquired digital survey accurate cadastral database. To convince land owners, orthophoto maps were incorporated as a base. In Figure 5, the land parcels are shown with red lines and the existing boundary of river is shown with a blue line. The actual boundary of the river is shown with green colour. It can be clearly seen that the land owners have encroached the river for agriculture purposes.

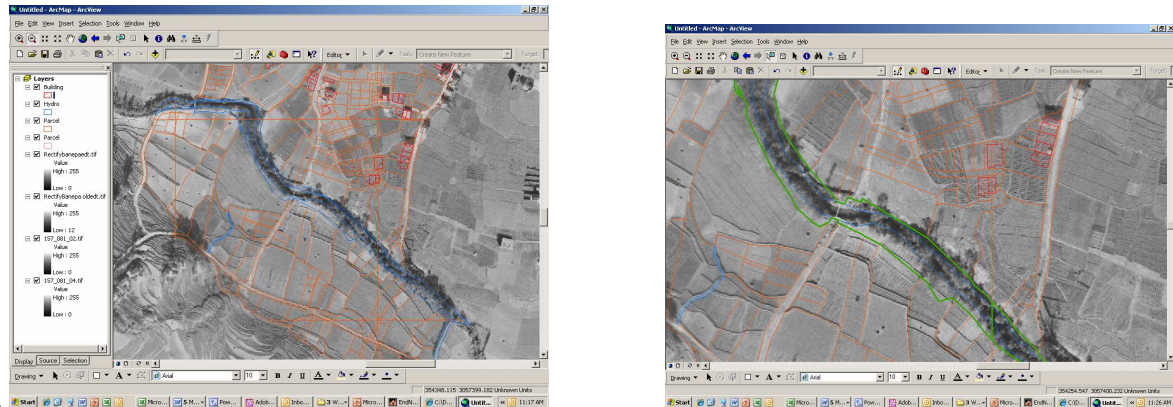


Figure 5: Integration of cadastral data with Orthophoto

Case Two: Encroachment in Public Open Space

The encroachment into public open space was again identified by integrating existing cadastral data and newly acquired digital survey accurate cadastral database. To assist in interpreting the data and to convince land owners, orthophoto maps were also used as a base layer.

In Banepa Municipality, many open public places have been allocated for public purposes. Increasingly however, these public places have been encroached upon and in some cases construction of building has taken place over them. In these situations there are social as well as environmental impacts on these activities. By integrating spatial data, the encroached public places can be identified. Figure 6, shows the development that has taken place on the public places.

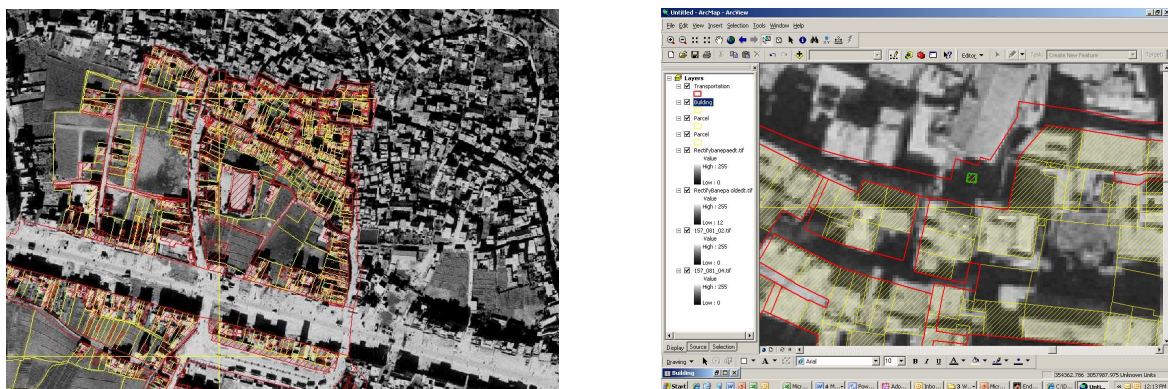


Figure 6: Encroachment on open spaces

Case Three: Encroachment in Roads

The encroachment upon roads was identified by integrating existing cadastral data, the digital survey accurate database and orthophoto maps.

In Figure 7, the roads are shown in red with buildings as well parcels shown in yellow. By integrating old cadastral data with newly acquired digital survey accurate cadastral data sets, the buildings encroaching upon the road could be determined. In figure 7 (right), it can be clearly shown that the building highlighted in green is encroaching the Arniko Highway of Banepa Municipality.

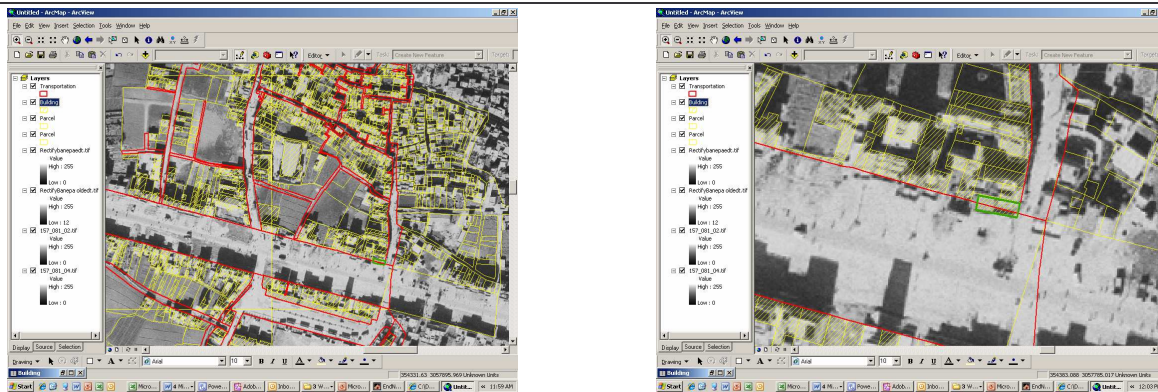


Figure 7: Building constructed with encroachment on Arniko Highway of Banepa Municipality

Conclusions

It is clear that catchment management necessitates the engagement of various stakeholders. To successfully engage stakeholders their role and responsibilities need to be clearly defined. In addition, stakeholders have an important role to play in helping to build SDI for sustainable catchment management. In this paper, the stakeholder analysis was found to be a useful tool for determining the roles, responsibilities and placement of various stakeholders. It enabled effective institutional and jurisdictional arrangements to be established based on the stakeholder's analysis. It was found that major government agencies, environmental related organisations, community groups and local authority are the key catchment authorities for building SDI and sustainable catchment management in Nepal. Organisations such as the Planning Commission, Ministry of Justice and Parliamentary Affairs, Ministry of Home, Ministry of Finance etc., have high power, so with respect to building the SDI, these organisations need to be "kept satisfied".

The three brief spatial analysis case studies have shown that spatial data can be used to support a range of land and catchment planning and management decision. Importantly, the relationship between people and land/water should be understood for effective catchments decisions to be made. Spatial data and the development of SDI offer great potential for catchment managers and decision makers. Finally, the paper has highlighted that the administrative hierarchy for building SDI may be insufficient for establishing SDI for sustainable catchment management which cuts across traditional as well as administrative boundaries.

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