AJLP & GS
African Journal of Land Policy and Geospatial Sciences

Using Social Network Analysis (SNA) to Assess the Availability of Spatial Data and Data Sharing Mechanisms in Rwanda

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ABSTRACT

This paper aims at analysing the extent to which spatial data are accessed and shared among stakeholders. It also uses Social Network Analysis to investigate institutional and individual behaviour in that process. Finally, it investigates the level of cooperation of all involved actors towards Spatial Data Infrastructure development. Results showed that public and private organizations have been individually engaged data collection and management. However, they are still using different standards and this has led to some disparities in terms of spatial data quality. Results also revealed the existing cooperation in data sharing that follow informal relationships through friendship or goodwill. In this case, organizations that use those data for public interest get them free, while those using them for income generation pay access fees. At the end, spatial data providers and users suggested the establishment of a spatial data sharing policy that will harmonize procedures in spatial data collection and dissemination.

Keywords:
Spatial data
Spatial data access
Spatial data sharing
Spatial data users
Data sharing policy

Received in: 04-03-2020
Reviewed in: 19-03-2020
Accepted in: 27-05-2020
Published in: 31-05-2020

Résumé

Cet article vise à analyser dans quelle mesure les données spatiales sont accessibles et partagées entre les parties prenantes. Il utilise également l'analyse des réseaux sociaux pour étudier les comportements institutionnels et individuels dans ce processus. Enfin, il examine le niveau de coopération de tours les acteurs impliqués pour le développement de l'infrastructure de données spatiales. Les résultats ont montré que les organisations publiques et privées ont été individuellement engagées dans la collecte et la gestion des données. Cependant, ils utilisent toujours des normes différentes, ce qui a conduit à certaines disparités en termes de qualité des données spatiales. Les résultats ont également révélé une coopération existante dans le partage de données qui se fait grâce à des relations informelles par amitié ou bonne volonté. Dans ce cas, les organisations qui utilisent ces données dans l'intérêt public les obtiennent gratuitement, tandis que celles qui les utilisent pour générer des revenus paient des frais d'accès. À la fin, les fournisseurs et utilisateurs de données spatiales suggèrent la mise en place d'une politique de partage des données spatiales qui harmonisera les procédures de leur collecte et diffusion.

Mots clés :
Données spatiales
Accès aux données spatiales
Partage de données spatiales
Utilisateurs de données spatiales
Partage de données

Reçu le: 04-03-2020
Evalué le: 19-03-2020
Accepté le: 27-05-2020
Publié le: 31-05-2020

1. INTRODUCTION

In 2005, the Government of Rwanda (GoR) approved the National Policy on Science, Technology and Innovation with the aim of setting key policies and strategies towards a knowledge-based economy. In the area of technology and innovation, a certain number of strategic plans have been established so far. These include the National Information and Communications Infrastructure (NICI) plan, Smart Rwanda Master Plan, and the Vision 2020, through its two implementing phases known as Economic Development and Poverty Reduction (EDPRS) 1 (2008–2012) and 2 (2013–2017). The two phases are currently being complemented by the National Strategy for Transformation 1 (NST1: 2017 – 2024), which is, at the same time, the ending phase of the Vision 2020 and the first phase of the upcoming Vision 2050. After almost 15 years, the impact of these plans has gone beyond the country's boundaries, and Rwanda is becoming a hub of ICT and innovation in Sub-Saharan Africa (RoR, 2017). Smart Africa Conference that attracts, every year, more than 1,000 delegates from 24 African countries and abroad is one achievement among others. Started in October 2013 in Kigali, Rwanda, Smart Africa has become a forum where African leaders, entrepreneurs, innovators, etc., meet and discuss the new ways of accelerating the socio-economic development of the continent through ICT and innovation (Smart Africa, 2013).

In the field of geospatial technologies, the availability and reliability of spatial data, Geographic Information Systems (GIS) tools, and techniques continue to affect positively the quality of policy decisions aimed at addressing developmental challenges. This falls in line with the current National Strategy for Transformation (NST1)(2017-2024), where the country is focusing on the use of geospatial technologies in key sectors of economic growth such as urbanization, agriculture, natural resources management, etc. (RoR, 2017). However, the ways in which available spatial data are generated and shared among key stakeholders are still problematic. In this regard, it has been observed that formal integral mechanisms of spatial data generation and sharing are not fully developed and/or implemented, and some institutions remain reluctant to share their data with the thirty parties. At the same time, other organizations are almost fully refraining from making their data freely accessible and open to the public. Besides this, some good examples are coming up. This is the case of Rwanda Land Management and Use Authority (RLMUA) that has recently launched the national geoportal (http://geoportal.rlma.rw/) where some of the spatial data on the country can be accessed for free, although the portal has lately faced an issue of going down for quite a while, and then comes back up, but it is now being maintained regularly. Similarly, the National Institute of Statistics of Rwanda has recently developed a new geoportal (http://geodata-nisr.opendata.arcgis.com/) and is up and running, and some of the socio-economic data (in addition to administrative boundaries data) is freely accessible to the public in both spatial-related and tabular formats. Another good example is related to land administration in the country where local people can access information on their plots via online master plans' platforms, as well as via mobile phone (especially during land transactions to ensure that the plot of interest is not legally bound to any other agreement).

Spatial data are the data that relates to the geographic location of features and their boundaries on earth, such as natural or man-made features, and describes both the location of a geographic feature and its attributes (Onsrud, 1995; De Montalvo, 2003; Harvey, 2006). Spatial data are collected at a high cost and their values come from their optimal use (Onsrud, 1995). Awareness about such high cost has pushed spatial data users and producers to formulate strategies avoiding duplication in spatial data collection and providing mechanisms allowing wide dissemination through data sharing. Spatial data sharing is defined as transactions in which individuals, organizations or parts of organizations obtain access from other individuals, organizations or parts of organizations to spatial data (Harvey, 2003; Omran, 2007). According to De Montalvo (2003) and Omran (2007), it is also defined as the process of providing spatial data to, or accessing spatial data from someone or someplace outside one's organizational unit. The same authors indicate that those transactions and relationships among key stakeholders are executed or implemented under certain terms and conditions.

This paper aims at analysing the extent to which public and private organizations in Rwanda cooperate in spatial data sharing and are willing to contribute to the ongoing SDI development for an optimal use of those data for the socio-economic development of the country. In addition, the study intends to identify key organizations involved in cooperation for spatial sharing. This study focuses mainly on organizational behavior because the technical issues of spatial data sharing are well studied and largely resolved, while institutional and individual behavior aspects are less well studied and require more attention (Harvey, 2006). In this regard, it is important to analyse how data sharing is dictated by shared norms and rules which facilitate or constrain the configuration of social networks. In the end, this analysis serves to give spatial data sharing both behavioural and institutional interpretation. The institutional interpretation of data sharing is captured through rules, norms, and structures of data sharing governance. This is how the Social Network Analysis (SNA) approach comes in. Results from this study provide a picture of current practices in spatial data sharing, which are the key drivers for the development and success of SDI in Rwanda.

2. MATERIALS AND METHODS

2.1 Study Area Description

Located in Eastern part of Africa, Rwanda is a land-locked country that covers a relatively small surface area (26,338 km^2). It is also characterised by a high topography that, from West to East, divides the country into three major landscapes namely highlands, central plateaus and lowlands. This elevation plays s big role in socio-economic development because it influences the spatial distribution of rainfall, temperature, vegetation cover and types of soils (Rwanyiziri et *al*., 2019, RoR, 2016). Finally the country has one of the highest population densities in Africa (495 inhabitants per square kilometer in 2018) and the population depends mainly on subsistence agriculture (Inamasiku and Ntagwirumugara, 2019; NISR, 2018). Nevertheless, the Government of Rwanda has been committed to the advancement of its population towards their high standards of living, with emphasis on quality of life, modern infrastructure and livelihoods, transformation for prosperity, promote and maintain Rwandans core values, and international cooperation and positioning (RoR, 2017; Gatete, 2016).

To achieve this, a number of mid-term and long-term strategic plans have been established including the Vision 2020, which is phasing out in June 2020, but also the Vision 2050 that is intending to boost the growth of the country in all aspects including agricultural transformation, industry development, infrastructure development, urbanization, etc. (RoR, 2017). This growth will also require innovative tools such as ICT and Geo-ICT as well as reliable data, including geodata that will continue to address major developmental challenges in Rwanda (RoR, 2017; Akinyemi, 2012; Akinyemi and Uwayezu, 2011). This study was conducted in the City of Kigali as well in four provinces namely Eastern, Western, Northern and Southern Provinces. All these administrative entities are subdivided into 30 districts, 416 sectors, 2,148 cells and 14, 816 villages. The following map is showing the location of 30 districts within the City of Kigali and in four provinces.

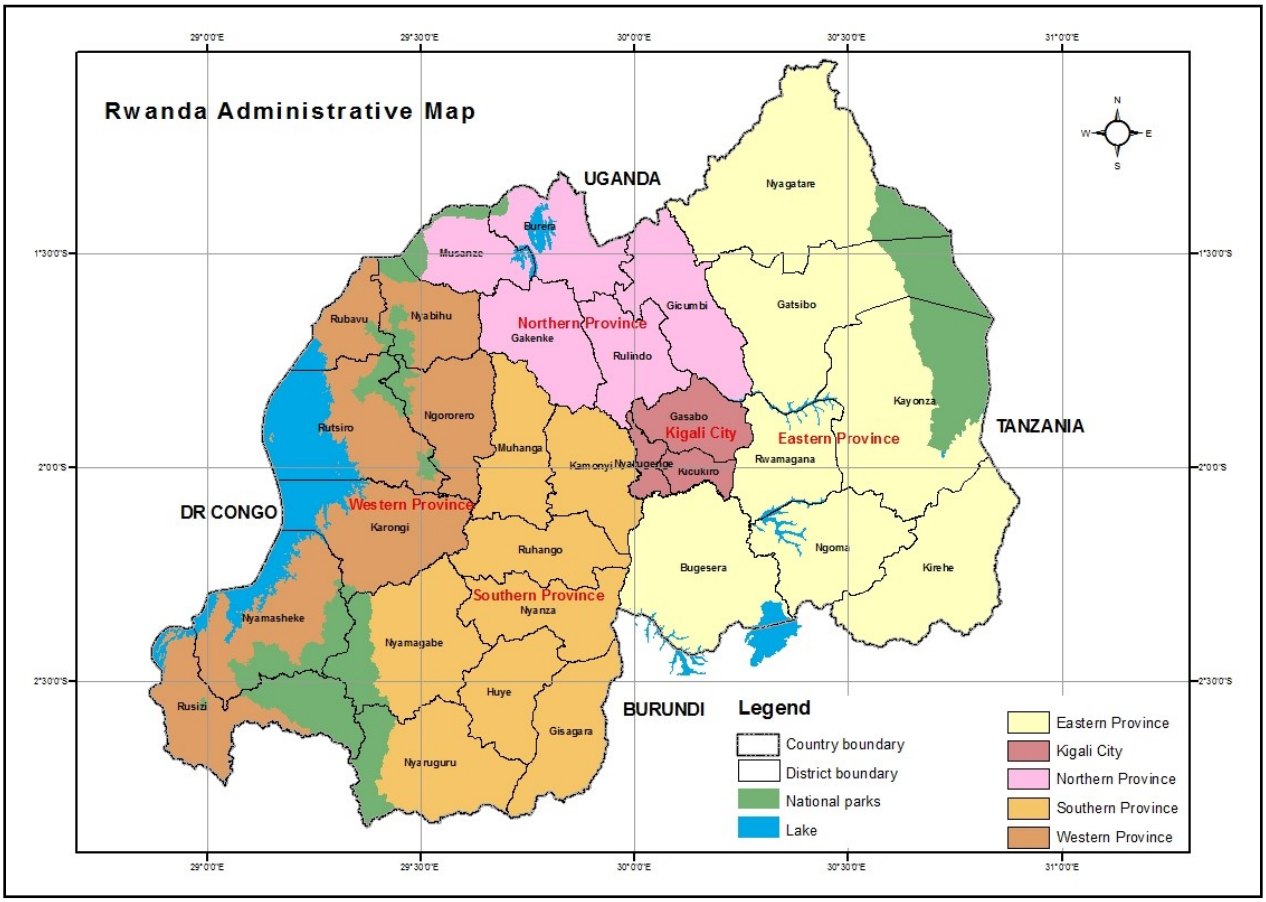

Fig. 1: Administrative Map of Rwanda (CGIS, 2019)

2.2 Data Collection Methods

Both secondary and primary sources of data were used in assessing the current cooperation in spatial data sharing among organizations operating in Rwanda. For the secondary, a well-consolidated literature review on spatial data availability, quality, quantity, format, infrastructure, and spatial data sharing mechanisms were carried out. Regarding the primary data, survey questionnaires, as well as interviews, were used. During that process, purposive sampling was used in selecting 29 organizations that participated in the survey. Most of the targeted institutions are located in the City of Kigali and others are located in the other four provinces of the country. All selected institutions participate in both

collecting and sharing geospatial data as they use them to perform their daily activities. Among the surveyed organizations, 86% are public whereas 11% are private or consultancy companies. For the higher learning institutions, only 3% of them were represented. In general, interviews and surveys by questionnaires were addressed to the staff participating in spatial data collection, management, and those who participate in decision-making about data dissemination or provision in each targeted organization. These interviews and survey questionnaire were designed in accordance with the scope of the study and covered the following aspects: data sources and custodians, existing data formats, data access and forms of access, spatial data sharing policy, the process for spatial data request and provision, conditions on access to spatial data (free access versus access for fees) coordination mechanism on data sharing in Rwanda and willingness of organizations to cooperate to SDI development.

2.3 Data Analysis

After collecting the data from the field, there was a preliminary data analysis consisting of summarizing and coding the data from survey questionnaires and interviews. Those data were organized in tabular form and grouped according to the themes addressed in the questionnaire. Based on this data, an analysis of both quantitative data was done to explain existing data sharing mechanisms, approaches, and conditions for data access and sharing among organizations. This analysis also helped in the configuration of relationships among key stakeholders involved in the data sharing process in the country. Specifically, collaborative data-sharing relationships between data producers and data users were analysed using SNA. This is because data sharing is considered as a social relationship, and individual organizations as participating actors and nodes in networks (Bodin and Crona, 2009). Social relationships can be kinship, friendship, cooperation or participation in a forum (Neal and Neal, 2011).

In this study, the expression "social relationship" is defined as the inter-organizational cooperation in data sharing. This cooperation processes comprised of actors such as data producers, providers, and users. That is why connections between organizations were depicted as the directed flow of data from the actor to another. In this regard, the approach that was adopted was to construct directed relationships through social network analysis. That is the In-Degree and Out-Degree centralities metrics were used to analyse these directed relationships. The In-degree centrality means request-receiving relationships whereas the Out-Degree centrality was used to mean the provision of data. Another metric that was used was the Betweenness centrality to explain the middle position that the actors hold in linking other actors who would not otherwise be connected (Presenza and Cipollina, 2010). In data sharing, this metric explains the boundary spanning (gatekeeper) and the coordinating position of the actors. To calculate and visualize these relationships, UCINET6.631 (a software package developed by Lin Freeman, Martin Everett, and Steve Borgatti, and is used for the analysis of social network data) was used. Netdraw visualization tool, version 2.161 (one of the windows programs used for visualization of social network data), as a component of UCINET6.631, was used to draw sociogram showing both nodes and collective data flow relationships to depict the structural institutional configuration in spatial data sharing.

UCINET6.631 packages were used to establish centrality metrics in order to identify organization controlling and coordinating the access in the data sharing process. For the control aspect, the in-degree

and out-degree centrality metrics were used. The in-degree is based on incoming links to the organization. This centrality is a proxy measure of individual actors to control others to access data. The out-degree centrality was used to determine central individual organizations with a greater connection to other actors and have more relationships to provide (give away) data without being connected to a single actor. Betweenness centrality was used to identify individual organizations that were unique in connecting two or many others which would not be otherwise connected (Blanchet and James, 2012). This measure was used to find out what organization plays the role of a coordinator or gatekeeper. This means the organization that connects peripheral organizations to central ones in spatial data sharing.

3. RESULTS AND DISCUSSION

This section presents the results from the survey on spatial data sharing mechanisms among key organizations that are using spatial data in Rwanda. It starts with the description of the types of existing spatial data that allow those organizations to engage in spatial data sharing collaboration and then discusses the existing systems or methods in which those data are collected and managed. In addition, it analyses the level at which users and producers of geodata collaborate and the existing social networks among them. Finally, it assesses different ways the policy SDI can be effectively developed in the country.

3.1 Main Available Spatial Datasets

Some of the visited organizations such as Rwanda Land Management and Use Authority (RLMUA), especially its Department of Surveying and Mapping, and the National Institute of Statistics of Rwanda (NISR) collect spatial data in the context of their mandate and mission which are to provide spatial data to the public. Other organizations collect and use spatial data as inputs for the achievement of their roles and responsibilities. Those data are captured and maintained using geospatial technology. Main datasets are those that are commonly nominated in a national context such as geographical feature names, elevation, hydrological networks, administrative boundaries, government units, ortho-imagery, cadastral information, transportation, and among others (Nebert, 2004). All these data are compiled from existing topographic maps, aerial photographs, remotely sensed images, historical records, legal documents, and direct field observations and surveys. For the case of this study, the following main datasets have been surveyed:

- **Administrative Boundaries:** these are spatial features corresponding to the administrative units of the including national, province, district, sector, cell and village boundaries.
- **Hydrography Features** include rivers, streams, canals, wells, wetlands and water bodies.
- **Topographic Data:** topographic maps that are available in Rwanda are at a 1:50000 scale. Information that is contained in topographic maps includes spot heights, contours lines, natural features like lakes and rivers, and forest coverage. Topographic data also exist in the format of shapefiles like contours that were extracted by Ghent University (Verdoodt, 2003) from the abovementioned topographic maps, and were updated since 2010, using spot height that were extracted from the aerial photographs by former RNRA, and other contour lines generated by private consultants at very large scale and for very small areas.

- **Aerial Photographs:** since 2008 the country is using high-resolution aerial photographs captured by Swede Survey, between 2008 and 2009, on behalf of the former Department of Lands and Mapping of Rwanda Natural Resources Authority (RNRA), currently the Department of Surveying and Mapping within Rwanda Land Management and Use Authority (RLMUA). However, some public institutions and private companies use high-resolution photographs captured by drones belonging to a private company entitled "CHARIS Ltd". They use them for a certain purpose and cover some small areas of the country such as forests or wetlands.
- **Land Cover and Land Use Data:** land cover is physical and biological cover of the earth's surface including artificial surfaces, agricultural areas, forests, natural areas, wetlands and water bodies. Land use is a territory described according to its current and future functional dimension as decided by the planners. Different categories of land use comprise residential, industrial, commercial, agricultural, forestry, recreational, and institutional buildings.
- **Health Facilities:** they include health facilities such as hospitals, health centers, and pharmacies.
- **Education Data:** they concern the geographical distribution of education facilities which include primary, secondary, and tertiary schools.
- **Cadastral Data:** are areas defined by cadastral bodies and were generated during the process of land registration by the former Department of Lands and Mapping of Rwanda Natural Resources Authority (RNRA)
- **Geology Data:** data described according to the composition and structure that include bedrock and geomorphology of the country.
- **Water Network Datasets:** they include water sources, water treatment plants, water reservoirs, pipelines, and water kiosks.
- **Electricity Network Datasets:** they include power plants, power transformer, power lines, and cabins.
- **Customers Location:** they include geographical location for water and electricity at the level of the household, industries, public institutions, etc.
- **Road Network:** is made of all roads, avenues, and streets of the country.
- **Commercial Data**: they include among others the shapefiles showing the location of banks, markets, and some supermarkets.
- **Communication Antenna**: they are features showing the geographic locations of the antenna of different telecommunication companies operating in Rwanda such as MTN, Liquid Telecom and Airtel.
- **Communication Cables and Optic Fiber:** are the wire or cable carrying communication signals such as telephone signals or internet signals, from one area to another.
- **Mining Concessions:** are areas of land that are allocated for mining purposes
- **Soil data:** are the datasets holding the information about the soil such as soil type, soil profile, soil concentration in ph, soil concentration in different saps and other chemical components like potassium, calcium, etc.

- **Climate Data:** are time series of measurements of sufficient length, consistency, and continuity to determine climate variability and change. The data include also weather variability information.
- **Tourist Data:** are the data showing the geographical distribution of tourist sites in an area of interest.

Given how relevant it is important to have an SDI in the country in order to have a framework for efficient and flexible use of spatial data, table 1 presents the available data in Rwanda in the context of SDI establishment. They are summarised into 5 major components:

- ***Data*** (i.e. core dataset, metadata, access and distribution tool);
- ***Technology*** (i.e. technological infrastructure used to access, use and communicate the data and/or outputs);
- ***Institutional Framework*** (i.e. institutional arrangements, policy for standards, policy for access, SDI organisation);
- **People** (i.e. data providers, value adders, data users); and
- **Standards** (i.e. spatial data standards, spatial data acquisition standards, database structure and content standards, data quality standards, etc.).

3.2 Spatial Data Collection and Management Systems

Results from the surveyed institutions have shown that spatial data producers and users are implementing the use of GIS tools in data collection and maintenance, and share those data in both analogue and digital formats. In this context, the technology which is used in spatial data collection reflects the types of spatial data format which are shared among key stakeholders. In general, both traditional data sharing and modern data sharing are practiced. According to the same results, 100% of the visited institutions maintain and provide spatial data in the form of printed maps or PDF format, and in digital format as a copy of or part of database. ESRI's software such as ArcGIS (10.6, 10.5, 10.4, 10.3, 10.2, 10.1, 10.0, 9.3) and Arc view 3.2 are the main software used by both private and public institutions to manage those data. Although the new versions of the ArcGIS software are available, some organizations (52%) keep using the old version like ArcView 3.2 and ArcView 3.1 in combination with the new versions (ArcGIS 10.6, 10.5, 10.4, 10.3, 10.2, 10.1, 10.0, 9.3). Another important information to know is that there is a new trend coming up where GIS professionals or experts are using open-source software such as QGIS, R, and many others. Their number is still few but may increase in the coming years. This is due to the expensiveness of commercial software produced by ESRI and/or other commercial companies.

Table 1: **Availability of Spatial Data in Rwanda and their Conformity to the Proposed Major Components**

S/N	Data	Technology	Institutional Framework and Policies	People	Standards[1]
1	Administrative Boundaries	- Acquisition: GPS (field survey) and digitising - Access and distribution: USB stick, E-mail, free online access via NISR geoportal (http://geodata-nisr.opendata.arcgis.com/datasets	-NISR is the data custodian and provider -Other key institutions: UR-CGIS, MINALOC, MINECOFIN and ESRI Rwanda -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Limited metadata standards
2	Hydrological Features	- Acquisition: GPS and digitising - Access and distribution: USB stick, E-mail	-RWA is the data custodian and provider - Other key institutions: UR-CGIS, WASAC, MININFRA and MINAGRI. -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
3	Topographic Data	- Acquisition: remote sensing and photogrammetry - Access and distribution: USB stick, E-mail, free online access via the RLMUA geoportal (http://geoportal.rlma.rw/)	-RLMUA is the data custodian and main provider -Other key institutions: UR-CGIS, NISR, ESRI Rwanda, MINAGRI, MININFRA and ESRI Rwanda -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
4	Aerial Photographs	- Acquisition: remote sensing, photogrammetry and orthorectification - Access and distribution: USB stick, E-mail, free online access via the RLMUA geoportal (http://geoportal.rlma.rw/)	-RLMUA is the data custodian and main provider -Other key institutions: UR-CGIS, MININFRA, MINAGRI, NISR and ESRI Rwanda -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
5	Land Use and Land Cover	- Acquisition: remote sensing, GPS - Access and distribution: USB stick, E-mail, free online access via the RCMRD portal (http://geoportal.rcmrd.org/)	-RLMUA is the data custodian and main provider -Other key institutions: MINAGRI, MININFRA, NISR, etc. -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Limited metadata standards
6	Health Facilities	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-MoH is the data custodian and main provider - Other key institutions: RBC, NISR and MININECOFIN.	-Main users and value adders: higher learning education, government institutions, UN	-Lack of official standards

[1] Although there are no official standards for most of the spatial data in Rwanda (from collection to distribution and use), most of the data in the country are projected in WGS 1984, ITRF 2000 and ITRF 2005 (global datums), and Arc 1960 (local datum). Moreover, the spatial data in Rwanda are principally found in three data formats: Vector, Raster, and CAD. The mainly used map projection in the country is UTM. However, there is no official publications regarding the related standards, and the country still lacks other spatial data standards such as those for data processing, data transaction, data quality, among others. Hence, there is urgent need for these and many more standards, in order for a continued support to promote knowledge-based economy in the country, with applications of geospatial technologies for advancement of different socio-economic sectors.

			-Lack of policy	agencies, NGOs, Private sector, individual consultants/researchers	
7	Education Data	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-MINEDUC is the data custodian and main provider - Other key institutions: RP, REB, HEC and MININECOFIN. - Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
8	Cadastral Data	- Acquisition: RTK, DGPS and GPS (field survey), Digitising - Access and distribution: USB stick, E-mail, mobile phone, free online access via the Kigali City platform: http://www.masterplan2013.kigalicity.gov.rw (for Kigali city)	-RLMUA is the data custodian and main provider - Other key institutions: NISR, MINALOC, RHA, Districts and MININECOFIN. -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Limited metadata standards
9	Geology Data	- Acquisition: remote sensing, field survey - Access and distribution: USB stick, E-mail	-RMB is the data custodian and main provider - Other key institutions: REMA, MoE and Mining Companies -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
10	Water Network Datasets	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-WASAC is the data custodian and main provider -Other key institutions: MININFRA, RURA and Aqua Virunga Ltd. -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
11	Electricity Network Datasets	- Acquisition: GPS (field survey) Access and distribution: USB stick, E-mail	-REG (EUCL & EDCL) is the data custodian and main provider - Other key institutions: MININFRA and RURA -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
12	Water and Electricity Customers Locations	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-WASAC and REG (EUCL & EDCL) are the data custodian and main providers - Other key institutions: MININFRA and RURA -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
13	Road Network	- Acquisition: GPS (field survey), digitising - Access and distribution: USB stick, E-mail	-RTDA are the data custodian and main provider - Other key institutions: MININFRA and RURA -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Limited metadata standards
14	Commercial Data	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-MINICOM is the data custodian and main provider	-Main users and value adders: higher learning education, government institutions, UN	-Lack of official standards

			- Other key institutions: RDB, PSF and MINECOFIN -Lack of policy	agencies, NGOs, Private sector, individual consultants/researchers	
15	Communication Antenna Locations	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-RURA is the data custodian and main provider - Other key institutions: RDB and Telecom Companies -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
16	Communication Cables and Optic Fiber Locations	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-RURA is the data custodian and main provider - Other key institutions: RISA, RDB, MININFRA and Telecom Companies -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
17	Mining Concessions	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-RMB is the data custodian and main provider - Other key institutions: RDB, REMA, MININFRA and Mining companies -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
18	Soil Data	- Acquisition: GPS (field survey), laboratory test - Access and distribution: USB stick, E-mail	-MINAGRI is the data custodian and main provider - Other key institutions: RAB, RLMUA and FAO -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Limited metadata standards
19	Climate Data	- Acquisition: remote sensing, meteorological stations - Access and distribution: USB stick, E-mail	-RMA is the data custodian and main provider - Other key institutions: REMA and MINAGRI -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards
20	Tourist Data	- Acquisition: GPS (field survey) - Access and distribution: USB stick, E-mail	-RDB is the data custodian and main provider - Other key institutions: MINICOM, PSF and Tour Operators -Lack of policy	-Main users and value adders: higher learning education, government institutions, UN agencies, NGOs, Private sector, individual consultants/researchers	-Lack of official standards

Source: Field Survey (2019)

One major reason, among others, for keeping the old versions is the high cost of the new versions, especially within the organizations that have a GIS unit, with different staff participating in spatial data capturing and handling. In that case, limited number of ArcGIS licenses push some staff to continue using the old versions. Both handheld GPS (92 %) and DGPS (8%) are used in data collection, but results from this study revealed that those data are collected using different projections and referencing systems, due to the lack of data collection standards. GPS is set according to, either WGS 84 when data will be integrated with other datasets that are internationally georeferenced, or UTM when the data will be integrated with other datasets that are referenced to the National grid. 36 % of the interviewed organizations use ITRF 2005 while 25% use both Arc 1960 and WGS 84. Research findings have also shown that 21% use WGS 84 and ITRF 2005 while 11% use WGS 84. Finally, the remaining 7% of interviewed organizations combine 3 datums that are ARC 1960, WGS84, and ITRF 2005.

The use of different datums reflects the absence of the standards in spatial data capturing and management (Table 1). As revealed by the survey, 79% of visited organizations do not follow any standard in spatial data collection and management, due to lack of knowledge of the most used standards. Moreover, there are not yet national standards that should be adopted by spatial data users in their daily GIS activities. Until now, only 21 % organizations such as the Centre for Geographic Information Systems and Remote Sensing of the University of Rwanda (CGIS - UR), Rwanda Land Management and Use Authority (RLMUA), and National Institute of Statistics (NISR) use some metadata standards in spatial data handling like the metadata, terminology and symbology standards (Table 1), all developed by ESRI Rwanda. Currently, the Department of Surveying and Mapping of RLMUA is developing the standards for spatial data collection and metadata that will be disseminated and recommended for the use by all geospatial data providers and users. In this regard, a policy on SDI development has been developed but not yet validated.

The study also investigated if the users and providers of spatial data have developed mechanisms to update spatial data they collect and use since the value of data comes from its accuracy and its update. Research findings showed that spatial data users and producers encounter financial problems that impend data updating activities. One of the examples include the case of the Department of Surveying and Mapping within RLMUA which is in charge of land registration and does not have the capacity to update the aerial photographs that are used in its daily activities. However, efforts are being made, and some organizations update their respective datasets, although not on a regular basis, as illustrated by the following Fig. 2.

The figure above (Fig. 2) shows that only 16 % of the visited organizations update their datasets every month, 8% after 6 months while 7% make an update every year. Most of the organizations (54 %) make an update if the updated data are required. There are other organizations that make an update after two years, while 11% of the organizations never update their datasets. In a few words, much work should be done in terms of updating the available data since the use of obsolete data leads to the dissemination of wrong information to the public.

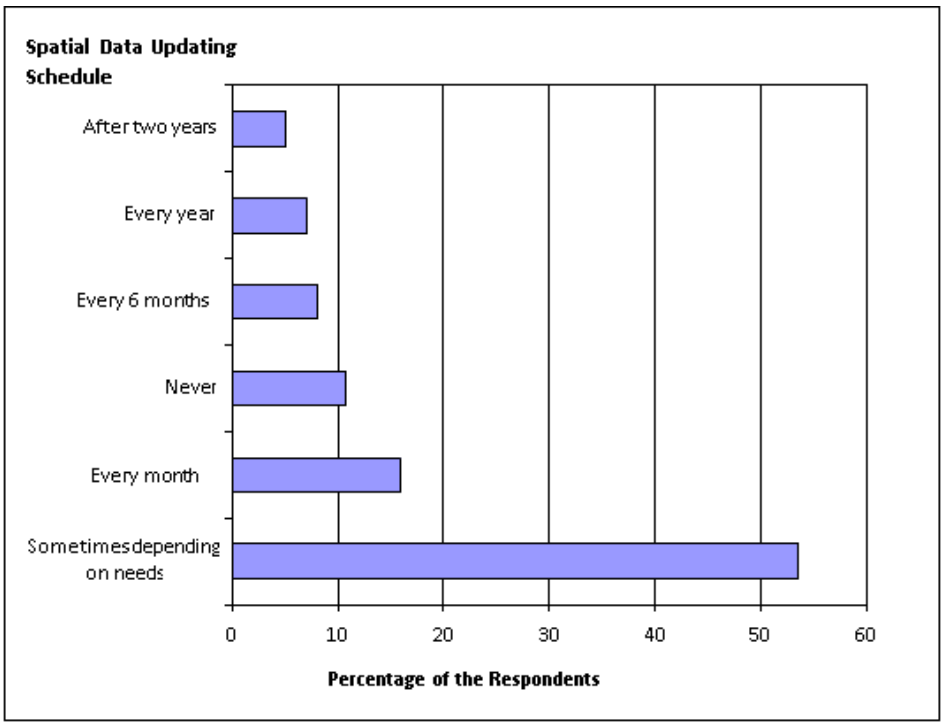

Fig. 2: Status of Spatial Data Updating in Rwanda (Field Survey, 2019)

3.3 Inter-organization Collaboration in Data Sharing

Since 2004, most of the public and private organizations in Rwanda have been engaged in spatial data sharing cooperation since 2004. After 15 years of this collaboration, it has been observed, however, that this excellent habit is not yet formalized. In fact, the need for use of geo-data generated by other institutions and the increasing awareness about the benefits from data sharing policy pushed those organizations to cooperate without any formal legal or institutional framework (Akinyemi & Uwayezu, E. (2011). In this regard, spatial data are shared on demand basis, and the request for spatial data provision is made through written or verbal communication. The most used way to get the needed geodata is to contact personally the officer in charge of their management in the hosting institution. The other way to get them is where two institutions have signed a Memorandum of Understanding (MoU) on spatial data sharing. However, this way is facing the challenge of heavy bureaucracy because it requires the use of formal channels that may delay geodata acquisition. Another challenge is related to the source of geodata to be shared. It has been observed that most of geodata are obtained through research or consultancy agreements between spatial data producers such CGIS and/or ESRI Rwanda and spatial data users such as RLMUA, RWFA, WASAC, etc. In this case, when spatial data users pay all fees for data collection and processing, they are immediately the right custodians of those geo-data. In that framework, spatial data producers cannot share those data with other organizations without a written authorization from the funding institutions.

Regarding the format of shared spatial data, 76% of interviewed organizations provide spatial data in form of printed maps, or PDF format, and in digital format as copy of database. Only 24% of visited organizations share spatial data in form of printed maps or in pdf format. Most of those organizations reported that the use of GI technology has highly enabled them to share spatial data in its digital format.

Besides the contents of data and forms of data sharing, inter-organizational collaboration is viewed as the flow of data from the providers to users. Fig. 3 shows the current flows of spatial data among the visited institutions. It shows central organizations playing bridging and influential role in spatial data sharing in the country. These organizations at the centre of the networks are the CGIS and RLMUA.

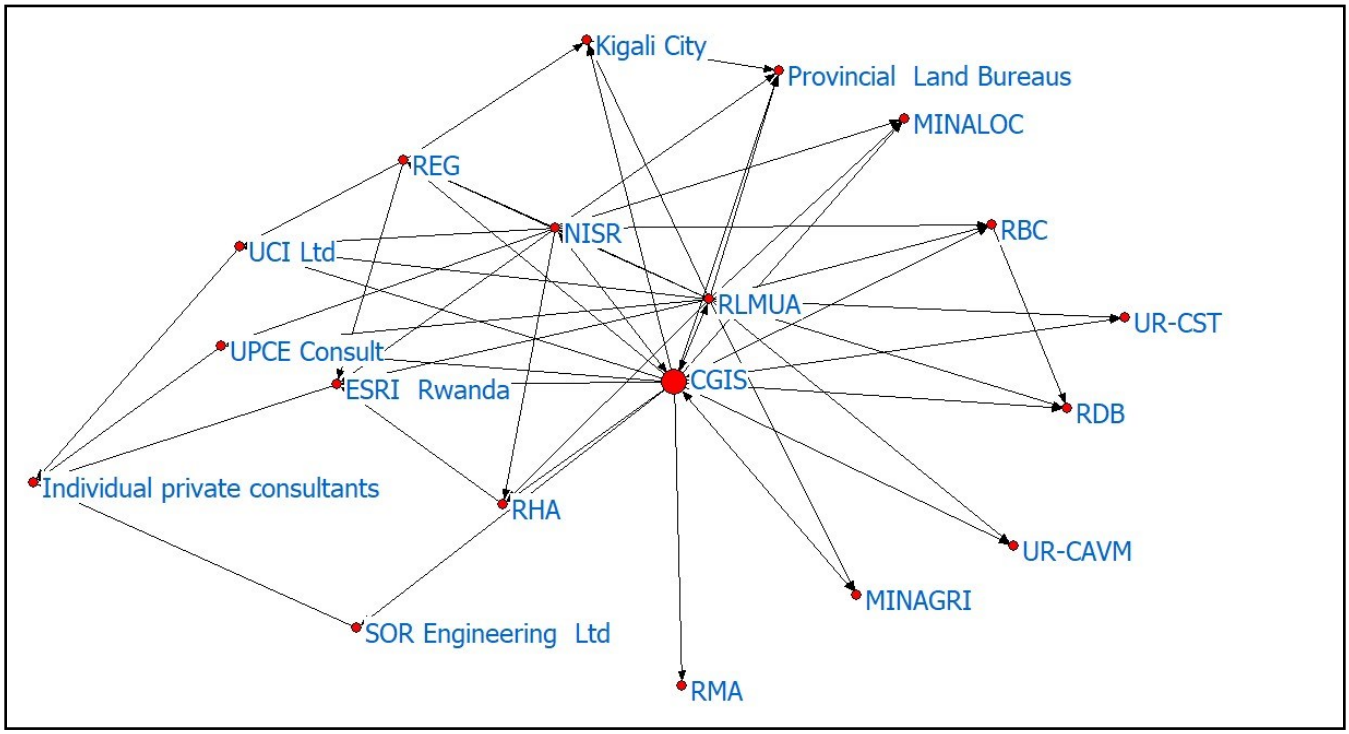

Fig. 3: Spatial Data Sharing Flows Between Public and Private Organizations

(Field Survey, 2019)

Looking at the figure the size of the cycles correspond to the outdegree centrality (the metrics for data provision). In this regard, this metrics show that RLMUA, NISR and CGIS are the central data providers, looking at the numbers of data requests they receive. Besides being data demand receiver, CGIS is also among the main spatial data producers since it is the most organization that provides data to other organization (Table 2). Most of other organizations such as University of Rwanda campuses (UR CST & UR CAVM), land bureaus in different districts, MINALOC, ESRI Rwanda and other private companies are among users and not among the providers of spatial data as illustrated by the following table.

All centrality indicators such as outdegree and indegree and betweenness correspond with formal position of actors (organization in data sharing). For instance, the fact data the CGIS and RLMUA are among few organizations that have signed an MoU reinforced their position in network (Fig. 2). The centrality indicators for the CGIS are respectively 17 (outdegree), 4 (indegree) and 42 (betweenness). This confirms its privileged position in terms of data production and provision, control and coordination, and it confirmed its formal position as bridging organization that can bridge the boundaries in data sharing among organizations. Regarding the position of RLMUA that signed a MOU with the CGIS, outdegree centrality indicator show that this organization retains the second position in terms of data production and data sharing (Table 2).

Table 2: **Actors Centrality Scores in Spatial Data Sharing**

S/N	Actors	Outdegree	Indegree	Betweenness
1	CGIS	17	4	42
2	UR CST	0	2	0
3	RLMUA	15	1	0
4	NISR	9	2	0
5	RDB	0	3	0
6	WASAC-EDCL	3	3	0.5
7	Kigali City	1	3	1
8	MINAGRI	1	2	0
9	Land Bureaus	0	4	0
10	UR CAVM	0	2	0
11	RBC	2	3	0.5
12	UCI Ltd	1	4	1.917
13	RMA	0	1	0
14	SOR Engineering Ltd	1	1	0.75
15	ESRI Rwanda	1	5	2.917
16	UPCE Consult	1	3	1.417
17	MINALOC	0	3	0
18	RHA	1	3	0
19	Individual Private Consultants	0	4	0

Source: Field Survey (2019)

4.4 Existing Initiatives on Spatial Data Sharing Policy in Rwanda

Spatial data sharing prescribes the legal process and conditions on spatial data access, the actors responsible for data provision and their power, the legal obligation of spatial data recipient on the use and the distribution of spatial data (Akinyemi, 2012). As it serves as a guideline towards the achievement of desired outcomes, the survey investigated if organizations are aware of any national policy to follow when they cooperate in spatial data sharing. Research findings have shown that there is no national policy guiding spatial data sharing in the country, although some organizations (only 14%) such as RLMUA, NISR and CGIS have developed internal policies on data access. Other organizations (86%) do not have any spatial data sharing policy, because there is no national policy standardizing the spatial data sharing practices in Rwanda. These organizations are engaged in data sharing through the traditional beliefs that consist in encouraging all spatial data users to cooperate with others for the optimal use of available resources. It is in line of that framework spatial data sharing mechanisms are still informal in many organizations.

A part from the organizations that have signed MoUs on data sharing (23%), the cooperation in that process is mostly influenced by the friendship among GIS offers and specialists (23%), goodwill of some

users thanks to their professionalism and smartness (34%), and awareness about the existing traditional culture to share geodata for the benefits of socio-economic development of the country (17%). The remaining proportion of interviewed organizations (3%) share geodata based on both goodwill and existing MoUs among them. The lack of data sharing policy was reported by 57 % of organization to be the main factor that obstructing data sharing in Rwanda. Other factors that limit the use of spatial data collected by other organizations include the compatibility problems due to use of different projection systems and standards, high cost for access to spatial data within the organizations applying the pricing policy, the long process in getting access to those data as there is no national policy to data sharing, among others.

Although there is no national policy on spatial data sharing, procedures related to spatial data provision may be included in the existing law on the access to information in Rwanda entitled "Law N° 4/2013 of 08/02/2013 relating to Access to Information Law'. Adopted in 2013, this law enables the public to access the information possessed by both public and some private institutions. It also recognizes the right to access to information, the procedures for accessing information, and compliance related issues (RoR, 2013). This study examined the extent to which institutions involved in data sharing process behave vis-à-vis this existing national law on data access, and research findings revealed that all visited institutions know the existence of that law, although they state that they do not follow any law or policy on access to spatial data.

However, this study revealed a certain relationship between what is being done by organizations involved in data sharing process and some requirements from the law on access to information. In fact, those organizations provide spatial data free of charge, define similar procedures on data access as prescribed by the law, and data are provided in both analogue and digital format as stated in the law. From this relationship, it can be concluded that the access to information law should be the block stone for the development of the policy or law on spatial data sharing in the country.

Regarding the cost of spatial data, there is no national pricing policy on it. However, some public organizations (only 10 %) charge fees to private spatial data users for access to those data. This is the case of RLMUA that charges 16,000 Frw per Km^2 aerial photographs taken between 2008 and 2009 to all private users. In the same framework, other organizations charge the access to spatial data basing on the expenses spent on data production. However, the study has revealed that they charge minimal fees compared to the cost of data collection. This study has also shown that private institutions charge fees for other private data users, but this is not applicable to public, academic and research institutions.

At the end, it has been observed that this "pricing approach" is not working in Rwandan context where, according to our survey, 90% of visited organizations share spatial data with all users for free. They do that because they consider spatial data as a resource to share free of charge with other stakeholders. In their opinions, free access to spatial data is a mechanism allowing its optimal use by the public. In this regard, respondents from the visited institutions argued that the appropriate policies and standards are highly needed to enhance spatial data collection and sharing in the country. They also highlighted the importance of developing data collection, data and metadata maintenance standards, as well as

copyright, privacy, and pricing policies in order foster the efficient use of geodata in the country. Finally, they put emphasis on data dissemination enhancement through partnerships to remove existing institutional barriers.

4.5 Willingness to Collaborate towards the Development of a National Spatial Data Infrastructure (NSDI)

As Rwanda is currently achieving good progress in socioeconomic development with a great emphasis on spatial planning in order to foster the development of the basic infrastructure, there is a need for the spatial data users to access the available and contribute to the country's development (RoR, 2017). In this regards, all spatial data providers and users who participated in this study support the development of a National Spatial Data Infrastructure (NSDI) that should contain different datasets, with metadata and that will offer a more comprehensive archive of geographic information useful in different domains for the socioeconomic development of the country. Respondents from those organizations argued that the Department of Surveying and Mapping within Rwanda Land Management and Use Authority (RLMUA) should lead this important action. According to them, RLMUA has to ensure the coordination of spatial data capturing, storage, processing and dissemination, and also work hand in hand with other data providers and users in the country and outside Rwanda so that the available data are of good quality and are shared among all key stakeholders (Akinyemi, 2012).

The coordinating body should also develop and implement the legal framework for the SDI development and govern all the works related to the spatial data handling and dissemination. They believe that the development of SDI will be enhanced by the inter-organizational cooperation in data sharing, but they reiterated that, prior to SDI development, spatial data sharing policy should be promulgated and enforced. In this regard, 76 % of interviewed people expressed their readiness to make available their data for the development of the SDI while only 24% argued that SDI should provide only metadata, and spatial data producers should provide spatial data. They expect that SDI development will solve the problems inherent to data duplication, cost saving in data collection, and use of the same standards in data collection and management. It is worth noting that the creation of SDI was initiated by CGIS in 2006. Ever since, different meetings were held and spatial data producers have been discussing the modalities for the establishment of such infrastructure.

In August 2013, a National Geo-information Committee Workshop took place in Kigali where key spatial data providers and users met in order to establish an interim National Geo-information Committee that was supposed to support the creation of an NSDI in the country. It was expected that NSDI would solve some problems pertaining to spatial data standards, and metadata with respect to data collection, custodianship, maintenance, security, and dissemination, copyright and pricing issues. Unfortunately, this committee didn't accomplish its mission on time due to the changes that happened within the former Rwanda Natural Resources Authority (RNRA) where the former Department of Lands and Mapping that was in charge of that mandate became Rwanda Land Management and Use Authority (RLMUA). It took a long time for the newly established institution (RLMUA) to rethink about SDI development in the country. It is against this background that, in August – September 2019, a national survey on existing geodata and data sharing habits in Rwanda has been conducted.

4. CONCLUSIONS

Spatial data is used by decision makers at local, regional and global levels, such as in land use planning, land management, environmental protection. Spatial data is expensive to collect and to maintain. It is for that reason some initiatives have been taken in order to foster access and exchange of those data, especially in Rwanda. These initiatives have resulted in the cooperation between spatial data producers and users. In that context, public and private organizations in Rwanda have individually engaged in spatial data collection and management. However, they use different standards and that leads to observe disparities in the quality in spatial data that are available in the country. Those organizations have also initiated spatial data sharing cooperation. Currently, spatial data sharing cooperation is following informal relations and most of them share spatial data based on friendship or goodwill.

Regarding the terms of accessing the existing spatial data, the results have shown that most of the organizations share spatial data free of charge with organizations using those data for a public interest, while the private organizations using those data for income generation pay access fees. Although most of those organizations have adopted similar procedures to spatial data access and provision, there is no any national policy guiding spatial data collection and dissemination. In the view of spatial data producers and users, the Government of Rwanda should promulgate spatial data sharing policy which will state clearly the terms on spatial data access for all users.

The policy should include also the standards for pricing in the case the users have to pay fees for access to spatial data held by government or non-government bodies, and leading the process of SDI development, as grassroots are willing to contribute to the implementation of that infrastructure. This policy should be implemented through an organization structures supported by a formalized network for data sharing. As depicted by the SNA results, SDI should encompass a statutory boundary organization (gatekeeper) like the CGIS to link national level SDI actors with grassroots ones. The mandate of this organization should be of coordinating data sharing among spatial data providers and users. However, this will require this boundary organization to increase its financial and technical capacities.

5. ACKNOWLEDGEMENT

The authors would like to thank all key informants and government authorities who helped in collecting data.

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7. LIST OF ACRONYMS

CGIS	Centre for Geographic Information Systems and Remote Sensing
DGPS	Differential Global Positioning System
EDGL	Energy Development Corporation Limited
EUCL	Energy Utility Corporation Limited
GPS	Global Positioning System
HEC	High Education Council
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINICOFIN	Ministry of Finance and Economic Planning

MINICOM	Ministry of Commerce
MININFRA	Ministry of Infrastructure
MoH	Ministry of Health
NISR	National Institute of Statistics of Rwanda
PSF	Private Sector Federation
RAB	Rwanda Agriculture Board
RBC	Rwanda Biomedical Centre
RCMRD	Regional Centre for Mapping of Resource for Development
RDB	Rwanda Development Board
REB	Rwanda Education Board
REG	Rwanda Energy Group
RHA	Rwanda Housing Authority
RISA	Rwanda Information and Society Authority
RLMUA	Rwanda Land Management and Use Authority
RMB	Rwanda Mines, Petroleum and Gas Board
RMS	Rwanda Meteorology Service
RNRA	Rwanda Natural Resources Authority
RP	Rwanda Polytechnic
RTDA	Rwanda Transport Development Agency
RURA	Rwanda Utility Regulation Authority
RWA	Rwanda Water Authority
SDI	Spatial Data Infrastructure
UCI	Union Card International
UR – CST	University of Rwanda College of Science and Technology
UR CAVM	University of Rwanda College of Agriculture and Veterinary Medicine
UR	University of Rwanda
WASAC	Water and Sanitation Corporation

8. KEY TERMS AND DEFINITIONS

Cadastral information: Comprehensive recordings of information related to extent, value, ownership, use, occupancy, etc. of the land in a country

Social Network Analysis (SNA): The process of quantitatively and qualitatively analysing and mapping social structures, carried our primarily by the use of networks and/or graphs. The main characteristics of the networks in SNA include nodes, such as people or things, and ties or links, which relate and/or connect them

Spatial Data Infrastructure: The framework of needed elements (i.e. people, data, technology, institutional framework, and standards) for a community to be able to make effective production, management, dissemination and use of spatial data.

Spatial Data Policy: A policy for which the main goal is to provide fundamental principles specifically related to spatial data, with required observance by all stakeholders through the process of generating, collecting, transforming, disseminating and using the spatial data. Some of the spatial data policies include spatial data sharing policy, pricing policy, among many others.