International Journal of Geo-Information

MDPI

Article

Assessing the Status of National Spatial Data Infrastructure (NSDI) of Bangladesh

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Abstract: National spatial data infrastructure (NSDI) is an essential framework for managing and sharing geospatial data across different sectors and organizations. In Bangladesh, the development of NSDI is still in its early stages, and there are several challenges that need to be addressed to ensure its effective implementation. This paper provides a comprehensive assessment of the status of NSDI implementation in Bangladesh using Eelderink's fourteen key variables. The paper examines the current state of NSDI implementation in Bangladesh, identifies strengths and weaknesses, and suggests recommendations for improvement. The findings suggest that while some progress has been made in establishing NSDI in Bangladesh, there are still significant challenges, such as limited funding; weak coordination among stakeholders; and a lack of skilled manpower, awareness, and capacity among users. To address these challenges, in this paper, we recommend several measures to improve the NSDI framework in Bangladesh. These include increasing funding support for NSDI development and maintenance, improving coordination among stakeholders through the establishment of a national coordinating body, enhancing awareness and capacity-building programs for NSDI users, and promoting the use of open data standards to improve data quality and interoperability. It is hoped that these recommendations will be taken into consideration by policymakers and other stakeholders to further enhance the development of NSDI in Bangladesh.

Keywords: national spatial data infrastructure (NSDI); NSDI assessment; metadata; interoperability; geospatial data

Citation: Rahman, M.M.; Szabó, G. Assessing the Status of National Spatial Data Infrastructure (NSDI) of Bangladesh. *ISPRS Int. J. Geo-Inf.* **2023**, *12*, 236. https://doi.org/10.3390/ijgi12060236

Academic Editors: Dev Raj Paudyal and Wolfgang Kainz

Received: 20 March 2023
Revised: 25 May 2023
Accepted: 5 June 2023
Published: 7 June 2023

1. Introduction

National spatial data infrastructure (NSDI) is a framework that enables the effective sharing and use of geospatial data within and between countries. NSDI has been defined as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data" [1]. The goal of NSDI is to improve decision making and resource management across all levels of government and the private sector through the sharing of geospatial information. It involves the coordination of various government, private sector, and academic institutions, as well as the establishment of common data standards and protocols [2–4]. NSDI is designed to enable the seamless integration and interoperability of geospatial data from different sources, making it possible to support a wide range of applications, from land management and environmental planning to emergency response and public health. NSDI has been established in several nations throughout the world as a result of a growing understanding of the significance of SDIs for national development. Many countries are implementing NSDI to better manage and utilize geographical datasets [5,6].

Recognizing the reality described above, Bangladesh began developing NSDI in 2016. The development of NSDI in Bangladesh has been a priority for the government in recent years. In 2016, the government formed a task force to develop a roadmap for NSDI

implementation. The task force identified several key components of NSDI, including data-sharing policies, technical standards, and institutional arrangements. Since then, the government has made progress in implementing NSDI. The NSDI of Bangladesh is being developed under the leadership of Survey of Bangladesh (SoB). SoB developed a national geospatial data portal "https://nsdi.gov.bd/ (accessed on 9 January 2023)" to provide access to geospatial data by different government agencies, other organizations, and individuals. This provides a central platform for the sharing and exchange of geospatial data, making it easier for decision makers and other stakeholders to access and use this information.

Like NSDI in other countries, the NSDI of Bangladesh has been developed considering different key aspects and standards. For example, the data schema is an important issue in developing NSDI. In the Bangladesh NSDI, the application schema was used to structure the data [7]. The application schema was used because it provides a way to describe the data structures and relationships used in geographic and spatial data, which makes it easier to share these data across different organizations and systems. In the context of the Bangladesh NSDI, the application schema specifies of the structure, content, and behavior of the NSDI portal that uses spatial data. It includes provisions for metadata in order to ensure that spatial data resources are properly documented and understood. Specifically, NSDI application schemas typically include metadata elements that describe the content, quality, and context of the data that the application uses or produces. The Survey of Bangladesh employs a range of data collection methods for its NSDI to ensure the accuracy and completeness of its geospatial datasets. By combining data from remote sensing, ground-based surveying, cadastral surveying, and other sources, the SoB is able to produce high-quality maps and other geospatial products that are used by government agencies, businesses, and other stakeholders in Bangladesh. The Bangladesh NSDI is still under development, with the aim of implementation in the coming days. However, to date, the state of development of the Bangladesh NSDI is unclear, and it lacks a setting that would encourage user exchange, accessibility, and sharing of spatial data. To the best of our knowledge, no systematic research has been conducted to assess and consider the constraints and challenges associated with the successful implementation of NSDI. It appears that the pre-existing conditions influencing SDI improvement within the country have not been considered. Against this background, it is very important to assess the current status of the NSDI of Bangladesh.

The assessment of NSDI is essential to ensure that it is meeting its objectives and to identify areas for improvement. NSDI assessment helps to determine whether NSDI is meeting its intended objectives and goals, allowing stakeholders to determine whether the technical infrastructure, data quality, and availability, as well as the use and uptake of geospatial data, are effective in meeting their needs. By assessing NSDI, it is possible to ensure that geospatial data are of high quality, accessible to stakeholders, and being used effectively to support economic development and decision-making processes [8]. Different countries have well-established approaches to assess NSDI. NSDI assessment in different countries typically involves evaluating the technical infrastructure, data quality and availability, and the use and uptake of geospatial data by different stakeholders. For example, the United States has a well-established NSDI that has been in development since the 1990s. The US NSDI is assessed periodically through the Federal Geographic Data Committee (FGDC) annual reports, which evaluate the status of NSDI implementation and identify areas for improvement [9]. Canada has a comprehensive NSDI that is assessed periodically through the Canadian Geospatial Data Infrastructure (CGDI) status report [10], which report evaluates the status of data and metadata standards, data sharing and collaboration, and the use of geospatial data in decision-making processes. Australia has a well-established NSDI that is assessed periodically through the Spatial Information Council (ANZLIC) [11]. The European Union has an NSDI that is assessed periodically through the INSPIRE Directive reporting mechanism [12]. However, in Bangladesh, there is no systematic approach to assess the status of its NSDI.

In view of the factors mentioned above, the aim of this study is to assess the current status of NSDI development in Bangladesh. The findings of this study will (i) assist policy makers in creating effective plans for constructing and upholding Bangladesh's national SDI, (ii) bridging the knowledge gap, and expanding the SDI community's understanding of the national and international standing of Bangladesh regarding SDI status.

2. Materials and Methods

NSDI assessment is the process of evaluating the maturity and effectiveness of a country's spatial data infrastructure. The purpose of an NSDI assessment is to identify strengths and weaknesses in the NSDI and to develop strategies and action plans to improve its effectiveness and sustainability. An NSDI assessment typically involves a comprehensive review of various aspects of the NSDI, including data, standards, policies, governance, and capacity building. The assessment may involve a combination of qualitative and quantitative methods, such as surveys, interviews, document review, and analysis of metadata and other relevant data sources.

Several methods are widely used to assess the maturity and effectiveness of an NSDI. Some common methods are (a) the SDI Readiness Index [8], (b) the organizational maturity matrix [13], (c) performance indicators [14], (d) the INSPIRE & NSDI State of Play methodology [15], (e) the Multi-View Framework [16], and (f) Eelderink's fourteen key variables to assess NSDI in developing countries [17].

The NSDI Readiness Index is a tool used to assess the readiness of a country or region to establish or enhance their NSDI. It is designed to evaluate the existing infrastructure, policies, and institutional arrangements that support the development and implementation of an NSDI [18]. The NSDI Readiness Index is typically used to identify gaps and areas for improvement in a country or region's readiness to establish or enhance their NSDI and to prioritize actions to address these gaps [8]. It can also be used to benchmark progress over time and to compare the readiness of different countries or regions. It provides a comprehensive framework for assessing legal and policy frameworks, geospatial information infrastructure, human and technical capacity, institutional frameworks and governance, and funding and sustainability [4]. Researchers have used the NSDI Readiness Index to assess NSDI readiness in various countries and regions, identifying gaps and establishing priorities for further development.

The NSDI Maturity Matrix is a tool that helps assess the maturity level of an NSDI. The NSDI Maturity Matrix is designed to provide a comprehensive evaluation of NSDI readiness, capability, and performance. The matrix consists of five levels of maturity, each with specific characteristics and criteria [19]. The NSDI Maturity Matrix is a useful tool for countries or regions to assess their NSDI maturity level, identify areas where improvement is needed, and prioritize resources and efforts accordingly. It can also be used as a benchmarking tool to compare the maturity level of NSDI [20].

Steudler's performance indicators are a set of indicators used to evaluate the performance of an NSDI [21]. The indicators were developed by Martin Steudler in his research on assessing the effectiveness of NSDI. The performance indicators are grouped into five categories. Steudler's performance indicators provide a comprehensive framework for assessing the performance of NSDI. By using these indicators, organizations can evaluate the effectiveness of their NSDI and identify areas where improvement is needed. The indicators also provide a basis for benchmarking and comparing the performance of NSDI.

The INSPIRE & NSDI State of Play methodology is a tool used to assess the implementation status of the INSPIRE Directive and the NSDI of a country. The methodology was developed by the European Commission to evaluate the level of implementation of INSPIRE across the European Union (EU) member states and to identify areas where further action is needed [15]. The methodology is based on a set of criteria that cover different aspects of INSPIRE implementation, such as data and metadata, network services, data policy, and governance.

The Multi-View Framework (MVF) is a comprehensive tool used to assess the maturity and effectiveness of NSDI. The MVF consists of four different views, each of which focuses on a different aspect of NSDI maturity [16]. Each view is further subdivided into a set of components or indicators that provide a detailed assessment of NSDI maturity. The MVF provides a flexible and adaptable framework that can be customized to meet the specific needs and requirements of different countries and regions. It is widely used by governments, international organizations, and other stakeholders to evaluate NSDI maturity and identify areas for improvement [19].

Eelderink's fourteen indicators to assess NSDI are a set of performance indicators used to assess the status of NSDI in developing countries [17]. To develop the indicators, the researchers compared and matched expert variables with case study variables related to NSDI assessment in developing countries. The expert variables were grouped into three categories based on their frequency of selection: most frequently selected variables, average selection variables, and least frequently selected variables. The most frequently selected variables were identified as most important for assessing NSDI in developing countries and were called the expert variables. Eelderink's fourteen indicators provide a comprehensive framework for NSDI assessment and are widely used by governments, international organizations, and other stakeholders to evaluate NSDI maturity and identify areas for improvement [4,22]. Since Eelderink developed these indicators for developing countries, we used these indicators to assess the status of NSDI development in Bangladesh. A short description of these indicators is presented in Section 3.

3. Eelderink's Key Variables

Eelderink's fourteen indicators to assess NSDI are a set of key variables that can be used to evaluate national spatial data infrastructure (NSDI) in developing countries. The 14 key variables for NSDI assessment in developing countries were identified through a research process that involved comparing and matching expert variables with case study variables. These variables were then investigated in six case study countries, and the initial list of identified variables was reduced to a smaller list of 49 feasible variables. Finally, the set of 14 key variables was selected based on a comparison of expert and case study variables. These key variables are considered important for assessing NSDI in developing countries, as they cover various aspects. The fourteen variables were grouped into six components. Table 1 shows the six components and respective key variables. A short description of each variable is presented below.

Availability of digital (geospatial) data refers to the availability and accessibility of digital data in a country. It encompasses various types of spatial data, including maps, satellite imagery, aerial photographs, geospatial databases, and other digital representations of geographic features and attributes. It includes the availability of data from different sources, such as government agencies, private sector organizations, and non-governmental organizations [19]. The availability of digital data is critical for NSDI implementation because it provides the foundation for spatial analysis and decision making. In developing countries, challenges related to data quality, completeness, and consistency may be encountered that need to be addressed. The availability of geospatial data is critical to the success of NSDI. To develop NSDI, it is important to ensure that geospatial data are accurate, current, and accessible to all stakeholders. This requires establishing data standards, metadata requirements, and protocols for data sharing and exchange.

Willingness to share refers to the willingness of NSDI stakeholders to share their data and information with others. It includes policies and regulations that promote data sharing, as well as cultural factors that may influence attitudes towards sharing. Willingness to share is important because it promotes collaboration among NSDI stakeholders and helps ensure that data are used effectively. Data sharing is essential for promoting economic and social development, but the willingness to share data is influenced by various factors. Data sharing is a critical component of the development of NSDI, as it enables different stakeholders to access and use geospatial data for a wide range of applications [23]. In the

context of NSDI development, data sharing refers to the exchange of geospatial data and metadata among different government agencies, non-governmental organizations, private companies, academic institutions, and citizens.

Table 1. Eelderink's fourteen key variables to assess NSDI in developing countries.

Component	Key Variable(s)
Data component	1. Availability of digital data
People component	2. Willingness to share
	3. Human capital (resources)
	4. Capacity building
	5. Awareness of NSDI concepts
Access network component	6. Delivery mechanism (availability)
Policy component	7. Funding
	8. Long-term strategic vision
	9. Institutional arrangements in place
	10. Existence of leadership
	11. Sociopolitical stability
Standards component	12. Availability of metadata
	13. Interoperability
Other component	14. Initiatives connected to NSDI (country's activity)

Human capital refers to the availability and quality of human resources needed for NSDI implementation. It includes factors such as education level, skills, experience, and motivation. Human capital is important because it provides the expertise needed for successful NSDI implementation [24]. The development of NSDI requires a skilled workforce with relevant knowledge and expertise. Human capital is an essential component of NSDI development, and it plays a crucial role in the success of NSDI implementation in any country, including Bangladesh.

Capacity building refers to the development of human resources and institutional capacity to support NSDI implementation. It includes training programs, workshops, and other initiatives aimed at improving the skills and knowledge of NSDI stakeholders. Capacity building is important because it helps ensure that NSDI stakeholders have the necessary skills and knowledge to effectively implement and maintain NSDI. Capacity building plays a vital role in the development of NSDI in any country [3]. Developing and implementing NSDI requires a range of technical skills, including geospatial data collection and analysis, database management, and data visualization. Capacity-building initiatives can help to build the technical expertise needed to design, implement, and maintain NSDI.

Awareness of NSDI refers to the level of awareness among NSDI stakeholders about the benefits and importance of NSDI. It includes initiatives aimed at raising awareness about NSDI among policy makers, decision makers, and other stakeholders. It also includes the knowledge and understanding of what NSDI is, how it works, and how it can be used for decision making, planning, and resource management. SDI awareness is important because it helps ensure that NSDI stakeholders understand the potential benefits of NSDI and are motivated to support their implementation [2].

The delivery mechanism is one of the key features of an NSDI. The delivery mechanism refers to the means by which geospatial data and services are made available to users, including the technologies, standards, and policies used to facilitate access, retrieval, and use [24]. It has been noted that an effective delivery mechanism is essential for ensuring the success and sustainability of an NSDI, as it can have a significant impact on the usability, accessibility, and reliability of geospatial data and services. A well-designed

delivery mechanism can help to promote collaboration, reduce duplication, and improve the quality and timeliness of geospatial information. Ideal access to spatial data should be appropriately, easily, rapidly, securely, and affordably provided through the NSDI [25]. The access network is particularly significant, since it is (relatively) transparent and obvious.

Funding is an important component of successful and sustainable implementation of NSDI. Securing funding is a critical issue for NSDI initiatives, not just in developing countries, but in all countries that seek to establish and maintain NSDI. NSDI initiatives require a sustained and ongoing investment of financial resources to ensure that they continue to meet the evolving needs of users and stakeholders. This investment is necessary to support the ongoing development and implementation of geospatial data policies and standards, the establishment of data-sharing agreements, the creation and maintenance of data catalogs, and the provision of access to geospatial data and services through web-based interfaces and other delivery mechanisms [16]. This variable assesses the availability and adequacy of funding for NSDI development, including government funding, international aid, and private sector investment. In developing countries, funding for NSDI development may be limited due to competing priorities, political instability, or lack of awareness about the benefits of NSDI. Adequate funding is essential to support activities such as data collection, infrastructure development, capacity building, and stakeholder engagement.

A clear vision for NSDI development is critical to guide decision making and resource allocation. This variable assesses the existence and clarity of a national vision for NSDI development. A clear vision can help to align stakeholders around common goals and objectives, prioritize activities based on their importance and feasibility, and communicate the benefits of NSDI to a wider audience [3]. A long-term strategic vision is considered very relevant in the dynamic NSDI environment. NSDI is a complex and evolving infrastructure that requires ongoing investment and commitment to ensure its success. A long-term strategic vision can help to guide decision making and investment in NSDI and ensure that the infrastructure is able to adapt to changing needs and technological advances. A long-term strategic vision for NSDI should consider a range of factors, including the needs of users and stakeholders, technological developments, and national policy priorities. It should also consider the resources required to establish and maintain NSDI over the long term and how these resources can be secured [4].

Effective institutional arrangements are necessary to coordinate NSDI development across different sectors and levels of government. This variable assesses the adequacy of institutional arrangements for NSDI development in developing countries. Institutional arrangements may include legal frameworks that govern data sharing and access, organizational structures that facilitate coordination among different agencies, or technical standards that ensure interoperability among different systems. Institutional arrangements for NSDI development are critical to ensure that NSDI is developed in a coordinated and effective manner [26]. Developing an NSDI requires the involvement of multiple stakeholders, including government agencies, private sector organizations, academia, and civil society organizations. Effective institutional arrangements can help to ensure that these stakeholders work together in a coordinated and collaborative manner and that the NSDI is developed and maintained in a sustainable way.

Leadership is crucial in the development of an NSDI because it involves bringing together multiple stakeholders, including government agencies, private industry, academic institutions, and non-profit organizations, to work together towards a common goal. Leadership helps to coordinate efforts, establish a clear vision, foster collaboration, encourage innovation, ensure data quality, and secure funding collaboration [19]. Without strong leadership, the development of an NSDI may be fragmented, uncoordinated, and ineffective.

Political instability can hinder NSDI development by creating uncertainty and disrupting progress. This variable assesses the level of sociopolitical stability in developing countries as it relates to NSDI development. Political instability can manifest in different ways, such as civil unrest, corruption, or changes in government. These factors can affect

the availability of funding, the ability to attract and retain skilled personnel, or the willingness of stakeholders to participate in NSDI development activities. Continued sociopolitical stability and commitment are crucial to developing NSDI [26]. An NSDI requires long-term planning and sustained commitment from governments and stakeholders to ensure its success. This includes developing policies, legal frameworks, and institutional structures that support data collection, management, and sharing across multiple organizations and levels of government. Sociopolitical stability is essential for the creation of an environment that is conducive to the development and implementation of an NSDI. This includes ensuring that there is a stable political environment and a supportive public policy context for NSDI [1]. It also involves engaging with stakeholders across different sectors and levels of government to build consensus and support for NSDI.

Geospatial metadata comprise information about geospatial data that provides details about their content, quality, and context. Metadata are important because they helps users understand the content and characteristics of geospatial data, which is essential for effective use and interpretation. Geospatial metadata typically include information such as the data source, date of creation, accuracy, resolution, coordinate system, and projection [27]. Metadata may also include information about the data format, distribution, and access rights. The use of geospatial metadata is critical for the effective management and sharing of geospatial data, particularly in the context of NSDI.

Interoperability refers to the ability of different systems to work together seamlessly, effectively exchanging and using information with minimal effort from the user. In the context of NSDI, interoperability is essential for data sharing across different organizations and sectors [28]. This variable assesses the level of interoperability among different components of NSDI in developing countries. Interoperability may be hindered. In the context of geospatial data, interoperability is important because it allows different organizations, agencies, and stakeholders to share and use geospatial data in a consistent and coordinated manner [7]. Interoperability is a critical component of NSDI because it enables the integration and sharing of geospatial data among different government agencies, organizations, and stakeholders. Interoperability allows geospatial data to be accessed and used across different sectors and levels of government, improving coordination and collaboration and reducing duplication of effort.

Initiatives connected to NSDI assess the existence and effectiveness of initiatives that support SDI development in developing countries, such as capacity-building programs, technical assistance, and knowledge-sharing networks. Initiatives to connect stakeholders with NSDI are vital to ensure the effective sharing and use of geospatial data in a country [19,29]. The success of NSDI depends on the active participation and collaboration of different stakeholders, including government agencies, non-governmental organizations, private companies, academic institutions, and citizens. Connecting stakeholders with the NSDI involves creating awareness and understanding of the benefits of geospatial data and the potential applications of NSDI [19]. This can be achieved through various initiatives, such as capacity building and training programs, workshops, conferences, and outreach activities.

4. Results and Discussion

Eelderink's fourteen key variables were presented in Section 3. These variables were used to assess the status of NSDI in Bangladesh. The variables were categorized into six components. In this section, the findings of our study are presented with respect to those six components.

4.1. Availability of Digital (Geospatial) Data

The availability of geospatial data in Bangladesh has improved in recent years, with the government and private sector investing in geospatial technologies and infrastructure [30,31]. The Survey of Bangladesh is the national agency responsible for conducting surveys, mapping, and providing geospatial information in the country [32]. The agency has a

mandate to provide mapping and surveying services for the entire country, including topographic, cadastral, hydrographic, and geodetic surveys.

The data for NSDI in Bangladesh were collected from a variety of sources to ensure the accuracy and completeness of its geospatial datasets. One of the primary data collection methods is remote sensing, which involves collecting data from satellite and aerial imagery. The SoB has access to high-resolution satellite imagery from various sources, in addition to freely available satellite images, which is used to produce topographic maps and monitor changes in land use and land cover [33]. In addition to remote sensing, the SoB also employs ground-based data collection methods. This includes using surveying equipment such as GPS (global positioning system), total stations, and electronic distance meters to capture accurate measurements of elevation, distance, and other geospatial data. Field surveys are conducted by trained surveyors who physically visit the site and take measurements using these instruments. Another important data collection method is cadastral surveying, which involves mapping the legal boundaries of land parcels and registering them with the government [34]. This is typically done using field surveys and interviews with landowners and other stakeholders. The NSDI authority also collaborates with other government agencies, NGOs, and private companies to collect and share geospatial data. This helps to ensure that the agency has access to the most up-to-date and accurate information for its mapping and surveying activities.

In addition to the Survey of Bangladesh, several government organizations in Bangladesh create geospatial information necessary for the functioning of their organization [35]. This information is subsequently made available to the general public on a website as part of the Digital Bangladesh policy. The GeoDASH geoportal website is managed by the Bangladesh Computer Council (BCC) with support from the World Bank to facilitate the sharing of geospatial information with the Department of Disaster Management (DDM), which falls under the Ministry of Disaster Management and Relief. In addition, the BBS established the Bangladesh GIS Portal (BGISP) with the goal of consolidating geospatial information from Bangladesh on a single platform and began releasing information in May 2019. Data are also provided by agencies such as RAJUK, LGED, BFD, BMD, BWDB, and others. Furthermore, the DLRS and WARPO have created a web-based system for information sharing, although it is only intended for internal use. While each system is established independently, the BFD forest information system was established based on GeoDASH, similar to the way the NSDI-PS was established by the NSDI-PP, indicating that a common framework has been employed. Some other organizations are also involved in producing spatial data, including the Department of Environment, the Water Development Board, the Roads and Highways Department, the Bangladesh Space Research and Remote Sensing Organization (SPARRSO), the Institute of Water Modelling (IWM), the Center for Environmental and Geographic Information Services (CEGIS), and various utility companies. Many of these agencies and organizations have established their own geospatial data portals to make their data available to users.

Although many organizations produce a variety of geospatial data, maintaining the accuracy and quality of geospatial data is challenging in Bangladesh due to limited resources, limited technical support, limited data sharing protocols, and the absence of a proper metadata standard.

To ensure the production of accurate spatial data and their availability for NSDI in Bangladesh, the SoB should adopt a comprehensive approach with a focus on capacity building and training programs for stakeholders involved in data collection, processing, and management. This will enhance their skills and knowledge related to spatial data acquisition techniques, ensuring accurate and reliable data. Additionally, establishing standardized protocols and guidelines for data collection will promote consistency and uniformity across stakeholders.

4.2. Willingness to Share

In the context of Bangladesh, available studies suggest that several challenges hinder the willingness of stakeholders to share data. A study suggested that lack of trust and collaboration among stakeholders, concerns around data security and privacy, and the absence of a legal framework for data sharing are major factors that hinder data sharing [36]. While private organizations are willing to share data, they are less willing to share data that could be used by competitors. Data pricing is another important factor determining the willingness to share data. A lack of awareness and understanding of the benefits of data sharing also contributes to reluctance among stakeholders. Some organizations perceive data as a valuable asset and hesitate to share it for competitive reasons or a lack of incentives to collaborate (Amit et al., 2021). Both government and private organizations are concerned about the ownership of data. Organizations spend money to produce data; however, once the data are shared, they may be used by third parties without prior consent and without paying a fee for the data. This is one of the major obstacles to data sharing in Bangladesh. While government officials recognize the importance of data sharing to achieve sustainable development goals (SDGs), concerns around data privacy and security, as well as the lack of data infrastructure, hinder willingness to share data [35].

To resolve these challenges and promote data-sharing willingness, several steps can be taken in Bangladesh. First, there is a need for the development of a national data-sharing policy and legal framework that outlines the principles, guidelines, and mechanisms for sharing data across sectors. Different countries have developed data-sharing policies to effectively share data among stakeholders. For example, the government of India and state governments generate and compile large volumes of data for their specific needs, including scientific and technical data. However, the lack of standardized formats poses a challenge for interoperability. Access to data has been proven to lead to scientific breakthroughs, economic development, and public benefits. Recognizing the value of non-sensitive data generated with public funds, the National Data Sharing and Accessibility Policy (NDSAP) was introduced in 2012 in India to make such data available for legitimate and registered use. The aim of the policy is to increase accessibility and sharing of non-sensitive data among registered users for scientific, economic, and social development purposes. Over the years, various government organizations have published their non-sensitive data in accordance with the guidelines outlined in the Right to Information Act of 2005, emphasizing transparency and accountability "https://dst.gov.in/national-data-sharing-and-accessibility-policy-0 (accessed on 12 January 2023)". Second, capacity-building programs should be implemented to enhance the technical skills and knowledge of data management, sharing, and interoperability among stakeholders. Third, incentives and recognition of data sharing can play a significant role in motivating stakeholders. Acknowledging and rewarding organizations and individuals who actively contribute to data-sharing initiatives through recognition, grants, or other benefits can encourage participation and create a positive environment for collaboration in Bangladesh.

4.3. Human Capital

The status of human capital in NSDI in Bangladesh shows a mix of strengths and challenges. While there is a pool of skilled professionals in geospatial technologies, such as GIS and remote sensing, and relevant training programs offered by the government and academic institutions, there is still room for improvement [33,35]. In Bangladesh, the availability of human capital with the necessary skills and expertise for NSDI development is limited. The development of NSDI requires a multidisciplinary approach that involves professionals from various fields, including urban planning, surveying, GIS, remote sensing, and computer science. However, the availability of such professionals is limited in Bangladesh, which hinders the implementation of NSDI.

To enhance human capital, efforts should be made to provide continuous training and capacity-building programs; promote research and development activities; create a supportive work environment; establish knowledge-sharing platforms; and foster col-

laboration between academia, government, and industry. By focusing on these aspects, Bangladesh can strengthen its human capital in NSDI, ensuring a skilled workforce capable of effectively driving the development and implementation of spatial data infrastructure.

4.4. Capacity Building

In Bangladesh, capacity-building efforts for NSDI development are underway, but more needs to be done to enhance the skills and knowledge of professionals involved in NSDI development [37]. One of the key challenges associated with capacity building for NSDI development in Bangladesh is the limited availability of skilled professionals. Capacity-building efforts should focus on enhancing the skills and knowledge of professionals involved in NSDI development, such as surveyors, GIS specialists, and remote sensing experts.

Another critical aspect of capacity building for NSDI development is the development of appropriate institutional frameworks. It has been noted that institutional frameworks, such as the establishment of a centralized body to coordinate and manage NSDI development activities, are essential for successful NSDI implementation in Bangladesh.

The government of Bangladesh and other stakeholders involved in NSDI development should continue to invest in capacity-building initiatives to ensure the successful implementation of NSDI in the country.

4.5. Awarness of NSDI

Awareness of NSDI is another crucial variable in the context of Bangladesh. It is important for policymakers, decision makers, and other stakeholders to have a clear understanding of the benefits and potential applications of NSDI. Awareness can be raised about NSDI through targeted initiatives that educate stakeholders about the role of geospatial data in decision making, planning, and resource management [15].

The level of NSDI awareness in Asian countries varies depending on the country and its stage of development. Some countries have well-established NSDI, while others are still in the early stages of development [2]. In general, more developed countries in Asia, such as Japan, South Korea, and Singapore, have a high level of NSDI awareness. These countries have been implementing NSDI for several years and have established policies and programs to promote NSDI awareness and utilization.

The current status regarding NSDI awareness in Bangladesh shows both progress and areas that require further attention. Over the years, efforts have been made by the SoB to raise awareness about NSDI and its benefits among stakeholders in Bangladesh. The SoB has conducted workshops, training programs, and outreach activities to educate government agencies, non-governmental organizations, academia, and private bodies about the importance of geospatial data and associated applications in decision making and planning. However, despite these efforts, there are still challenges in terms of widespread awareness and understanding of NSDI among key stakeholders in Bangladesh [37]. Limited resources, capacity constraints, and a lack of technical expertise hinder the dissemination of NSDI concepts to a wider audience. Many government agencies, private companies, and individuals have yet to fully grasp the potential of geospatial data and its practical applications. To address these challenges, it is crucial to continue to expand awareness campaigns, knowledge-sharing initiatives, and capacity-building programs. Sector-specific awareness programs can be developed to highlight the direct relevance of geospatial data in various fields, such as agriculture, urban planning, and disaster management. Collaborative efforts between government agencies, academia, and industry should be strengthened to share success stories, best practices, and case studies showcasing the benefits of NSDI implementation.

4.6. Delivery Mechanism

The National Geoportal of Bangladesh is an important component of the NSDI of Bangladesh. The National Geoportal of Bangladesh is not still fully operational. It is envi-

sioned that the geoportal will provide a centralized platform for the discovery of, access to, and use of geospatial data and services from various government agencies and departments in Bangladesh. According to the proposed 2022 NSDI policy of Bangladesh, there would be three types of access to NSDI: (a) open access, (b) registered access, and (c) limited access. Some of the data can be openly accessed from the NSDI. Anyone can access those data without registering with the NSDI. Some data would be provided to registered user only. Sensitive data would be restricted to only selected organizations/individuals as decided by the authority.

4.7. Funding

Funding for long-term, sustained operation and maintenance of NSDI is a crucial issue in Bangladesh, as it is in many other developing countries [32]. Establishing an NSDI requires significant investment in terms of financial, technical, and human resources [22]. However, sustaining the NSDI over the long term requires ongoing investment and commitment. Expenditure for NSDI includes investment in infrastructure development, data collection and acquisition, data management and maintenance, capacity building and training, technology and software procurement, governance and policy development, outreach and awareness campaigns, and monitoring and evaluation efforts. However, investment in infrastructure development is the most fundamental. The development of NSDI in Bangladesh is partially supported by the Japan International Cooperation Agency (JICA). The project was officially endorsed by the Minister of Planning on 20 July 2020. The government of Bangladesh approved a total budget of BDT 140,500,000 for this endeavor, with the funding allocated from both domestic and international sources. Of the total budget, BDT 32,700,000 was contributed by the Bangladesh government, while the remaining portion was supported by Japan. The budget for the project was deemed valid in February 2020 and remained in effect until June 2022, allowing for a comprehensive implementation and completion of the NSDI development initiatives within the specified time frame "http://www.sob.gov.bd/site/page/6b78eb1e-c3e9-4d5a-925b-2dfc05456ec9/- (accessed on 2 February 2023)". However, the time frame has been extended. According to the draft NSDI policy of Bangladesh, the long-term funding for NSDI would be from two sources: budget allocation by the implementation committee and funding allocation by the data preparation organization (stakeholders). The data preparation organization supports funding because they control the data and data pricing and enjoy the financial benefit of their own data. Despite the progress made in securing funding for NSDI in Bangladesh, challenges remain. Limited financial resources, competing priorities, and bureaucratic procedures can hinder the efficient allocation and utilization of funds. There is a need for continuous advocacy, strategic planning, and effective resource management to ensure the availability of adequate and sustainable funding for NSDI initiatives in Bangladesh. To address this issue, the government of Bangladesh could consider establishing a dedicated funding mechanism for NSDI. This could involve allocating a specific budget for the operation and maintenance of NSDI or setting up a separate funding stream through which stakeholders can contribute to the operation and maintenance of NSDI.

4.8. Long-Term Strategic Vision

Bangladesh has made significant progress in establishing its NSDI infrastructure, but sustaining and expanding the infrastructure over the long term will require a strategic and coordinated approach. The NSDI of Bangladesh has a clear long-term strategic vision. The long-term strategic vision of NSDI in Bangladesh focuses on integrating and standardizing geospatial data, promoting data accessibility and sharing, building capacity and human resources, fostering institutional collaboration and governance, ensuring sustainability through long-term funding, and engaging stakeholders and creating awareness. The aim of the vision is to establish a comprehensive and sustainable geospatial data framework that supports evidence-based decision making and contributes to national development goals. To achieve this vision, several initiatives have been undertaken by the SoB. The SoB has

been actively working on strengthening the institutional framework for NSDI implementation, including the establishment of the NSDI Steering Committee and Technical Committee. These committees are responsible for formulating policies, guidelines, and standards for geospatial data management and promoting coordination among relevant stakeholders. Efforts have been made to improve data collection, management, and sharing mechanisms. Achieving the long-term strategic vision of the NSDI in Bangladesh faces several challenges. These include fragmented spatial data availability, ensuring data quality and accuracy, financial sustainability, institutional coordination, and enhancing public awareness and participation. To overcome these challenges, efforts should focus on strengthening data collection and management systems, promoting collaboration and data sharing, implementing data quality assurance mechanisms, exploring diverse funding sources, establishing clear institutional frameworks, and engaging with stakeholders through awareness campaigns and open data policies. Continuous monitoring, evaluation, and adaptation will be crucial to ensuring the success of NSDI in Bangladesh.

4.9. Institutional Arrangements in Place

In Bangladesh, institutional arrangements have been established to ensure that NSDI development is coordinated and effective [38]. The Survey of Bangladesh (SoB) serves as the lead agency for NSDI development in Bangladesh. The SoB is responsible for coordinating NSDI development efforts across government agencies, private sector organizations, academia, and civil society organizations.

Stakeholder involvement is a key element of institutional arrangements for NSDI development in Bangladesh. The SoB works closely with other government agencies, including the Ministry of Land; the Ministry of Environment, Forest and Climate Change; the Department of Disaster Management; the Department of Environment; the Water Development Board; the Roads and Highways Department; the Local Government Engineering Department (LGED); the Bangladesh Space Research and Remote Sensing Organization (SPARRSO); the Institute of Water Modelling (IWM); and the Center for Environmental and Geographic Information Services (CEGIS), as well as with private sector organizations, academia, and civil society organizations. The SoB has also established a National Geospatial Data Sharing Policy to guide the sharing of data among stakeholders.

Legal and regulatory frameworks for NSDI development in Bangladesh include the Geospatial Data and Services Act, which provides a legal framework for the collection, use, sharing, and dissemination of geospatial data. The Act also establishes a Geospatial Data Committee to oversee the development and implementation of NSDI in Bangladesh. However, the implementation of this act has faced challenges. One of the critical reasons for the limited implementation of the Geospatial Data and Services Act is the lack of awareness and understanding among relevant stakeholders. Many government agencies, private organizations, and individuals were not fully aware of the provisions and requirements of the act, leading to non-compliance and inadequate enforcement. Another factor hindering the implementation is the lack of technical capacity and resources [35]. Moreover, the complex nature of data sharing and coordination among multiple stakeholders poses a significant challenge. Achieving seamless data sharing and collaboration requires strong coordination, trust building, and effective governance mechanisms. Insufficient coordination and collaboration among these stakeholders hindered the implementation of the Act. Additionally, institutional and bureaucratic barriers impeded the effective implementation of the Act.

4.10. Existence of Leadership

Developing NSDI in Bangladesh is a complex process that requires strong leadership at both the national and local levels. In Bangladesh, the Survey of Bangladesh (SoB) serves as the lead agency for NSDI development; therefore, its leadership is crucial for the success of the NSDI initiative [32]. While there have been notable efforts by government agencies and stakeholders to develop and implement NSDI, there are certain areas that require

attention. One of the key challenges of leadership in NSDI is the ability to bring together multiple stakeholders and foster collaboration towards a common goal. In Bangladesh, leadership in NSDI development has shown some progress in this regard, with government agencies, private industry, academic institutions, and non-profit organizations actively participating in the process [34]. However, there is room for improvement in terms of creating a more inclusive and participatory approach that involves a wider range of stakeholders, particularly at the grassroots level. The development of NSDI requires coordination among various government agencies and departments by the lead agency. This coordination in Bangladesh is challenging due to the hierarchical structure of government institutions, differences in data management practices, and limited interagency collaboration.

Effective leadership for NSDI development in Bangladesh also requires strong technical expertise in geospatial data and technology. The leadership must be able to assess the current state of geospatial data in the country; identify data gaps and needs; and develop strategies for collecting, managing, and disseminating data. To overcome the leadership complexity in NSDI development in Bangladesh, fostering strong leadership at both the political and administrative levels is essential. This involves appointing knowledgeable and experienced individuals who can provide strategic direction, facilitate coordination, and drive the implementation process. Additionally, establishing dedicated NSDI governance structures with clear roles and responsibilities can enhance leadership effectiveness.

4.11. Sociopolitical Stability

Sociopolitical stability in Bangladesh is a challenge for the development of NSDI. Bangladesh is a developing country that has undergone significant political and social upheaval over the years. While the government has recognized the importance of developing NSDI, there have been challenges in maintaining policy continuity and ensuring sustained commitment.

One of the main challenges in Bangladesh is the frequent changes in political leadership, which can impact the continuity of policies and initiatives. Additionally, there may be competing priorities for government resources, which can make it difficult to allocate sufficient funding and attention to the development of NSDI. Challenges in terms of sociopolitical stability in Bangladesh represent obstacles to NSDI development and implementation. Political instability, social unrest, and governance issues can disrupt the continuity of initiatives, hinder policy implementation, and create uncertainty among stakeholders. These challenges may result in delays, resource constraints, and difficulties in sustaining long-term projects.

4.12. Availability of Metadata

In Bangladesh, efforts have been made to develop and maintain geospatial metadata for the effective management and sharing of data. The Survey of Bangladesh (SoB) developed the guidelines for metadata standard in 2020. However, the guideline is still in draft form and not finalized. In order to develop the guidelines, the authority used the "Specifications of Japan Metadata Profile (JMP) 2.0", "Instruction Manual of JMP 2.0", "Metadata Instruction for 1:25,000 Scale Map" (by SoB), "INSPIRE Data Specifications Template", NWRD (by WARPO), and ISO 19115-1 (Metadata—Part 1: Fundamentals). The draft metadata elements include many types of information, including but not limited to information about the spatial reference system, accuracy, scale, resolution, and lineage of the data, as well as other details, such as data ownership, access restrictions, and update frequency. According to draft metadata guidelines, there should be three properties of metadata: M (mandatory), C (conditional), or O (optional). The guidelines also set minimum required fields of metadata (of spatial data), which consist of data name, abstract, date of creation, spatial extent, coordinate system, administrative area, responsible organization, and contact information. To improve the metadata of NSDI in Bangladesh, it is essential to establish a comprehensive metadata framework that includes standardized formats, consistent documentation practices, and clear guidelines for metadata creation and maintenance.

Capacity-building programs should be implemented by the SoB to train professionals in metadata management, ensuring that they have the necessary skills to accurately describe and document spatial data. Collaboration between data producers, custodians, and users is also crucial to ensure the consistent and up-to-date creation of metadata.

4.13. Interoperability

The current status of interoperability of NSDI in Bangladesh is relatively limited. Although there have been efforts to establish data-sharing mechanisms and standards, the implementation and adoption of interoperability practices are still in the early stages. One of the key challenges is the lack of a comprehensive and coordinated governance framework for NSDI, which hinders the effective collaboration and integration of spatial data across stakeholders. In Bangladesh, efforts are being made to establish interoperability in NSDI through the development and implementation of standards for data formats, metadata, and exchange protocols [35]. The Survey of Bangladesh (SoB) is working to establish a comprehensive geospatial data infrastructure that supports interoperability and data sharing among stakeholders.

One of the key initiatives in this regard is the development of a metadata catalog that provides information on the geospatial data available in the country. The metadata catalog includes information on the data format, quality, and source, as well as information on how the data can be accessed and used. This metadata catalog is an important tool for establishing interoperability in the NSDI, as it provides a standardized and consistent way for different stakeholders to access and use geospatial data. To improve the interoperability of NSDI in Bangladesh, it is crucial to adopt and implement international standards for data formats, metadata, and data exchange protocols. Additionally, the development of data exchange agreements among stakeholders is essential to establish clear terms and conditions for sharing and using spatial data. A well-defined governance framework should be established to coordinate the efforts of different stakeholders, while a centralized data infrastructure or NSDI can serve as a common platform for data storage and management. Implementing comprehensive metadata catalogs and promoting capacity-building initiatives will further enhance the interoperability of NSDI in Bangladesh, ensuring seamless integration and accessibility of spatial data across various sectors and organizations.

4.14. Initiatives Connected to NSDI

In Bangladesh, initiatives to connect stakeholders with the NSDI are essential to ensure the effective sharing and use of geospatial data and to achieve the full potential of the NSDI in supporting sustainable development and improving the well-being of citizens. To connect stakeholders with the NSDI, the Survey of Bangladesh (SoB) has undertaken several initiatives, such as capacity building and training programs, workshops, and outreach activities. For example, the SoB has organized training programs and workshops for government officials, private companies, and non-governmental organizations to improve their skills and knowledge in geospatial data management, analysis, and visualization.

5. Conclusions

This paper provides a comprehensive assessment of the current status of the NSDI in Bangladesh. The paper identifies the strengths and weaknesses of the NSDI and evaluates its performance against key indicators. The findings suggest that while some progress has been made in establishing NSDI in Bangladesh, there are still significant challenges that need to be addressed. These challenges include limited funding; weak coordination among stakeholders; and a lack of skilled manpower, awareness, and capacity among stakeholders. This NSDI assessment provides an overview of the status of geospatial data and information management in Bangladesh.

This research includes a review of the policies, laws, and regulations related to geospatial data and information management, as well as an analysis of the current data collection, management, and sharing practices in Bangladesh. The assessment was based on

Eelderink's fourteen key variables [17], which were developed to assess the NSDI of developing countries. The result of the assessment is presented in Section 4. The assessment of Bangladesh NSDI reveals that progress in NSDI development in the country is remarkable, while challenges remain to be overcome. Some key variables are in a good position, and some are in a weak position.

The assessment findings suggest that while some progress has been made in establishing NSDI in Bangladesh, there are still significant challenges that need to be addressed. These include limited funding; weak coordination among stakeholders; and a lack of skilled manpower, awareness, and capacity among users. These challenges have hindered the effective implementation of NSDI in Bangladesh and have limited its potential benefits for different sectors. This study reveals that the technical infrastructure for NSDI in Bangladesh is underdeveloped. The country lacks adequate hardware, software, and skilled personnel to support geospatial data management. Additionally, the existing technical infrastructure is fragmented, with different agencies using different data formats and standards, making data sharing difficult.

Data sharing is limited in Bangladesh, with government agencies often reluctant to share data with other agencies or the private sector due to concerns around data privacy and security. There is also limited public awareness about the importance of data sharing and its potential benefits.

To improve the NSDI in Bangladesh, some important measures should be taken. First of all, it is important to strengthen the policy and regulatory framework by enforcing existing laws and policies, providing clear guidelines for data collection and management, and promoting data sharing. Second, technical capacity should be built-up by providing training for government personnel and promoting the use of open-source software and tools. Third, public awareness about the importance of geospatial data and data sharing should be increased by conducting outreach programs, developing data portals, and promoting data literacy. Finally, funding is an important issue that must be considered for the sustainable operation of NSDI. The government of Bangladesh should develop a dedicated funding mechanism to resolve this issue.

In conclusion, Bangladesh has made some progress in developing an NSDI, but there are significant challenges that need to be addressed. Improving the policy and regulatory framework, data collection and management practices, technical infrastructure, funding, and data sharing can help to build a more robust and sustainable NSDI that supports evidence-based decision making, promotes economic development, and helps to address some of the most pressing social and environmental challenges facing the country.

The study is subjected to several limitations that need to be acknowledged. First, the assessment of NSDI implementation in Bangladesh was based on a limited set of indicators and data sources and may not have capture the full range of issues and challenges facing the framework. Secondly, we relied on secondary data sources, which may have limitations in terms of accuracy and reliability. Thirdly, we did not provide a comparative analysis of NSDI frameworks across different countries in the region, which could have provided additional insights into the strengths and weaknesses of NSDI implementation in Bangladesh. Finally, we did not provide a detailed analysis of the policy and institutional factors that have influenced NSDI development in Bangladesh, which could have shed light on some of the underlying causes of its current status.

There are several potential future directions for research on NSDI implementation in Bangladesh. First, future research could focus on developing a more comprehensive set of indicators and data sources to assess the status of NSDI implementation in Bangladesh. This could involve conducting primary data collection through surveys, interviews, and case studies to capture a more nuanced understanding of the challenges and opportunities facing the framework. Secondly, future research could explore the policy and institutional factors that have influenced NSDI development in Bangladesh, including the role of different stakeholders and their interactions. Finally, future research could involve a comparative

analysis of NSDI frameworks across different countries in the region to identify best practices and lessons learned that could inform policy and practice in Bangladesh.

Author Contributions: Conceptualization, Md. Mostafizur Rahman and György Szabó; methodology, Md. Mostafizur Rahman; software, Md. Mostafizur Rahman; validation, Md. Mostafizur Rahman; formal analysis, Md. Mostafizur Rahman; investigation, Md. Mostafizur Rahman; resources, Md. Mostafizur Rahman; data curation, Md. Mostafizur Rahman; writing—original draft preparation, Md. Mostafizur Rahman; writing—review and editing, Md. Mostafizur Rahman and György Szabó; supervision, György Szabó. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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