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Past and Present Practices of Topographic Base Map Database Update in Nepal

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Abstract: Topographic Base Maps (TBMs) are those maps that portray ground relief as the form of contour lines and show planimetric details. Various other maps like geomorphological maps, contour maps, and land use planning maps are derived from topographical maps. In this constantly changing world, the update of TBMs is indispensable. In Nepal, their update and maintenance are done by the Survey Department (SD) as a national mapping agency. This paper presents the history of topographical mapping and the reasons for the lack of updates. Currently, the SD is updating the TBM database using panchromatic and multispectral images from the Zi Yuan-3 (ZY-3) satellite with a resolution of 2.1 and 5.8 m, respectively. The updated methodology includes the orthorectification of images, the pansharpening of images, field data collection, digitization, change detection, and updating, the overlay of vector data and field verification, data quality control, and printing map production. A TBM in the Dang district of Nepal is presented as casework to show the changes in the area and issues faced during the update. Though the present digitizing procedure is time-consuming and labor-intensive, the use of high-resolution imagery has made mapping accurate and has produced high-quality maps. However, audit and automation can be introduced from the experiences of other countries for accurate and frequent updates of the TBM database in Nepal.

Keywords: topographic base map; national mapping agency; updates; history; ZY-3; Nepal

1. Introduction

Topographic base maps (TBMs) are maps that show planimetric details and altimetric details, i.e., the portrayal of relief utilizing contour lines [1]. They are prepared and frequently updated by their National Mapping Agency (NMA). These maps portray detailed ground relief (landforms and landscape), drainage (lakes and waterways), forest cover, administrative zones, populated regions, transportation courses and buildings (counting streets and railroads), and other man-made features [2]. These have multiple utilities in the present day: any kind of geographic arranging or large scale design; earth sciences and numerous other geographic controls; hydrogeological, geotechnical, and other earth-based undertakings; structural building; and recreational uses like climbing and or hiking. TBMs are an important primary source of information for any land-related inventory, planning, and implementation of the development projects. Derived/administrative maps, thematic maps/land resource maps, and large-scale maps are required for nation-wide development, administration, and statistical purposes [3]. These maps are derived into various maps for landscape planning and management. Conveniently, TBMs are used to create 2D maps in which elevation is represented by contour lines. Though 2D maps are difficult to read by inexperienced users, 2D maps give the precise relative position of any point. Meanwhile, 3D maps are better for understanding the shape and topography of a location [4]. Any location on a 2D map has to be adjusted to the 'Z' value, i.e., the elevation at that place that is easily found in TBMs.

Meanwhile, the world is very dynamic. It is changing at a fast pace. New developmental works are being done, new roads are being constructed, cities are expanding, new buildings are being built, the course of rivers are changing, and forests are being converted into an agricultural zone. As many things are changing in topography, a regular update of TBMs is necessary [5]. Many NMAs around the world have their ways to update TBMs. Most old maps were handcrafted products created from stereo images and photographs that were manually digitized and manually compiled. However, updates are done globally using the digital devices and software using a secondary data source, primarily like the original TBM and Geographic Information System (GIS) database of the national map product. Most countries prepare TBMs at regular intervals. Swiss topomaps are updated in a cycle of six years with the dataset published every year [6]. The United States Geological Survey (USGS) updates the US topomaps on an interval of three years [7], with the ortho imagery from the National Agriculture Imagery Program (NAIP) with a resolution of 1 m [8]. Similarly, in Australia, Geoscience Australia did a recent update of TBM three years ago for urban areas, but the frequency of their updates is unknown [9]. Meanwhile, change in topography for many remote areas in Australia is infrequent, with updates to the data in these areas often on a 10-year cycle [10]. Likewise, Germany updates its topographic database on a five-year cycle [11]. Finland, on the other hand, has a revision cycle of 5–10 years [12]. In Brazil, TBMs are updated on an average of 29 years [13]. In Nepal, as an NMA, the Survey Department (SD) bears a responsibility to give the updated geo-information of the country to support multi-sector development activities and has a policy that indicates that updating of base maps should be carried out on a 10–20 year cycle using new air-borne or space-borne imagery [3]. These updates include gradually accurate topographical information collected with cutting edge technologies, data on altering land cover, enhanced transport networks, increasing developed areas, and other land use. Likewise, in some different cases, there are botches in the TBMs that must be found and rectified. The perfect case is to update territories with a high pace of progress more often. The updated material ought to be exhibited in any new series of maps [5].

Remote sensing (RS) technology is highly relevant in countries like Nepal where large areas are inaccessible for a ground survey. After the preparation of the original sets of TBMs in Nepal, there was no progress in their update because of a lack of technology, budget, and skilled survey professionals; additionally, finding information regarding such historic data was very much limited to articles from Nepalese journals and internal reports published by the SD and employee's experiences only.

For a developing nation like Nepal, without donor support, new aerial photography is relatively expensive because Nepal is a geographically diverse country ranging elevation from 60 to 8848 m [14]. It has varying weather. A higher region requires varying altitude and flight types, so aerial flight for a required area is virtually impossible. In such a case, only satellite imagery is the best and most cost-efficient, and recent support from the Chinese government and allocated budget from the Nepalese government initiated the first official update of national scale TBMs. Similarly, Nepal has started to produce many geomatics engineers [15] by starting geomatics engineering programs in different universities, hence increasing the number of skilled surveys professional and accomplishing more technological advancement to make the update procedure quick. In the present context, the SD uses the integration of GIS and RS technology for map updates. The SD is using high-resolution satellite imagery from the Zi Yuan-3 (ZY-3) satellite supported by China for TBM updates. This shows that Nepal has taken a great leap in the sector of the TBM updates. The ZY-3 satellite is the first civil high-resolution stereoscopic Earth mapping satellite of China. The overall objective is to compile a database to produce 1:50000 and larger-scale maps and to provide data for topographic mapping and resource mapping [16]. To ensure accuracy and reliability, ZY-3 adopts a large platform that is equipped with a double-frequency Global Positioning System (GPS) and more gyros. ZY-3 obtains a geolocation accuracy better than 15 m without Ground Control Points (GCPs), and it obtains a geolocation accuracy better than 3 m and a plane geolocation accuracy better than 4 m with GCPs, which completely satisfies 1:50,000 mapping precision [17]. ZY-3 images have been made freely available to the Nepalese government for five years.

To fill the literature gap and to document present works related to the TBM update in Nepal, this study was undertaken. In Section 2 of this paper, we present a review of past and present ways of updates, and we describe the methodology that is followed by the SD in updating TBMs, as well as problems and issues that occur during updating. In Section 3 of this paper, we present the casework of a TBM sheet in the Dang district. In Section 4, we discuss the factors that the SD is currently lacking, and which factors are necessary to make the progress faster, easier, and cheaper. Finally, Section 5 concludes the study.

2. Topographic Base Mapping in Nepal

2.1. Past Update Practices

During the mid-1960s, the Survey of India prepared TBMs of Nepal at the scale of one inch to one mile or 1:63,360 maps, which is popularly known as the one inch map series [5]. After that, in 1991, the topographical survey division of the SD prepared and printed a TBM titled Shivgunj, with a sheet number 2687 08C, but it was not distributed outside. This map was from the eastern part of Nepal and was of Shivajang of the Jhapa district. Subsequently in October 1993, with the support of the Government of Finland, toposheet samples, with sheet numbers 2785 02C and 2785 01, were printed on scales of 1:25000 and 1:50000, respectively, under the Eastern Nepal Topographic Mapping Project. Since that map was a base map, all of the natural features and man-made forms on the ground were included. The map was made from the technique of feature extraction from aerial photogrammetry using a stereo plotter. The map was created at a scale of 1:25,000 and 1:50,000. The projection system used for the map was a modified universal transverse Mercator [5].

The SD produced a new series of TBMs between 1992 and 2001 at the scale of 1:25,000 (for the Terai and middle mountains) and the scale of 1:50,000 (for the higher mountains and Himalayas) covering the entire country in paper print, and they subsequently converted all those maps into digital form by GIS technology and made they available to the users as National Topographical DataBase (NTDB). Data based on a 1:25000 sheet covers an area of 7′30″ by 7′30″, while that based on 1:50000 sheet covers an area of 15′ by 15′ [18]. The difference in data content is according to the change in scale.

TMBs of Eastern Nepal and Western Nepal were produced by the SD in co-operation with the Government of Finland. These maps were compiled from 1:50,000 scale aerial photography of 1996. Field verification was done in 1997. These maps covered the middle-mountains and Terai of Eastern and Western Nepal. There were total map sheets of 255 and 254 for Eastern Nepal and Western Nepal, respectively. The contour interval for the maps was 20 m. A total of six colors was used for the preparation of maps [19].

Similarly, the SD prepared TBM series of the Lumbini zone with the support of the Japan International Cooperation Agency (JICA) in 1993. These maps were compiled with aerial photographs from 1990. These maps had a contour interval of 10 m. The total number of map sheets was 81, and five colors were used for preparation [20]. Figure 1 shows the sheet index used by both donor associations in Nepal [19]. In the old TBMs, internal administrative boundaries were not demarcated on the ground. The names of places and other features were derived from existing sources and supplemented during field verification.

The SD has also prepared a geographical map of Nepal that shows general geographic information about an area including the locations of cities, boundaries, roads, mountains, rivers, coastlines, and ortho-photomaps of urban areas, as well as national geographic information. As the existing base maps of the Lumbini and Eastern zones are over a decade old, the SD has initiated a program for the total updating of these base maps 1:25,000 of the Lumbini zone for a couple of years. Many changes have occurred since the first edition in 1992 [19]. Hence, the need for the updating of the map series is an essential task.

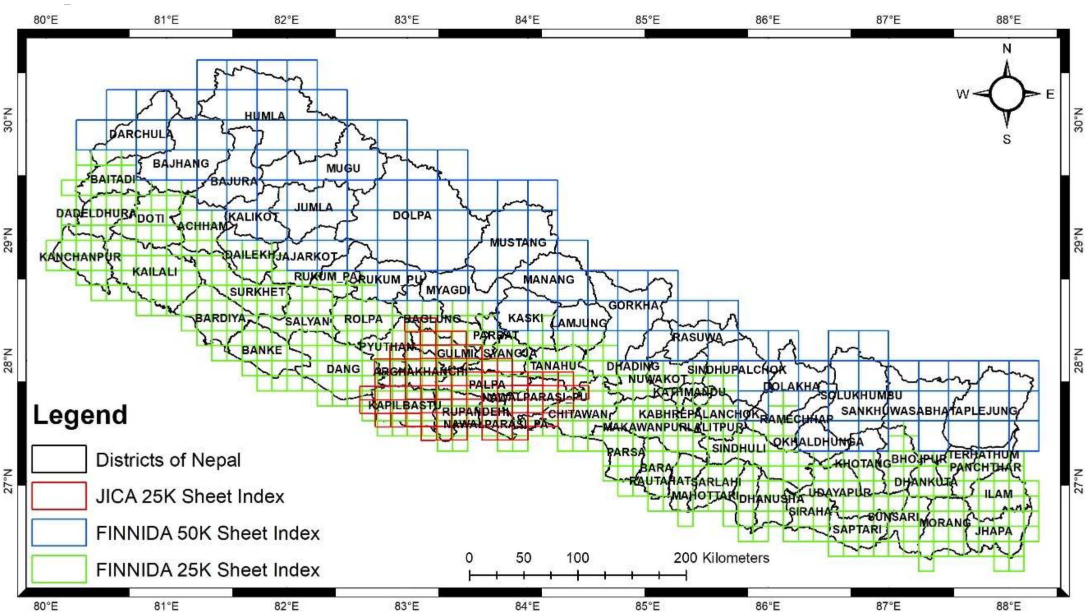


Figure 1. The coverage of different topographic mappings of Nepal during 1992–2001.

Though the topographical survey policy of the SD is to carry out an updating procedure every 10–20 years, this has not been the case. The process of field update has been taking place, but there was no progress in cartographic updates in Nepal for 15 years after the first TBM preparation. The cartographic update of the TBM of Nepal was started after the RS division was established under the topographical survey branch in 1998 AD. TBM update and printing started from the Lumbini district. The feature was initially updated using a low-resolution image like those from Landsat from the RS method, but, nowadays, high-resolution images are used. This work was done from the RS unit.

2.2. Present Update Process

The TBM update is currently undergoing in Nepal. The whole Nepal TBM update is being done in three phases. The TBM update of the Terai region, which goes from the Saptari district of Nepal in the east to the Bardiya district in the west. According to the TBM update committee, altogether, 208 sheets were mapped in the first phase. The case study presented here is one of the sheets that was updated during the first phase of the latest topographical map update. The first phase started in March 2019 and continued for almost 11 months. The second phase of topographical mapping is currently running in Hilly regions by forming seven groups. In the present update, the province and other internal administrative boundaries are based on the gazettes published by the Department of Printing and the Ministry of Communication and Information Technology, Government of Nepal on 10 March, 1 May, and 8 May 2017.

The methodology adopted by the SD for the TBM update includes satellite imagery acquisition, the orthorectification of imagery, the pansharpening of imagery, the georeferencing of imagery, the acquisition of a digital database of the TBM from the Geographic Information Infrastructure Division of Nepal (GIID), field visits, verification, digitization, quality control, and compilation. For this purpose, November 2018 satellite images were used. The images were from Chinese satellite ZY-3. These images were provided by the Government of China to Nepal. The panchromatic images had a resolution of 2 m, and the multispectral images had a resolution of 5 m. The images had cloud coverage of less than 5% with a radiometric resolution of 16 and 32 bits. The images were georeferenced to make the images related to the ground coordinate system. For that, the planning of the ground control point collection was done in satellite images covering the entire working area. There was no pre-marking point for Ground Control Points (GCPs) collection. The point was established in the junction of a road junction or the landmarks that were easily markable both in the ground and the image. For each image sheet, at least 5 GCPs covering corners and centers of images were planned. The GCPs were planned in such a way that most of GCPs lied in the overlap area of two or more images. This decreased the time taken for fieldwork and cost. Static GPS surveying was used for control surveys. The GPS observation was carried out from the known control point in the first phase. In the second phase, the observation data were processed in the Trimble software linked with Continuously Operating Reference Station (CORS) station from University NAVSTAR Consortium (UNAVCO). The processed data were then transformed from the World Geodetic System 84 (WGS 84) coordinate system to the Modified Universal Transverse Mercator (MUTM) system. Figure 2 shows the overall method followed in the current TBM update using ZY-3 in Nepal.

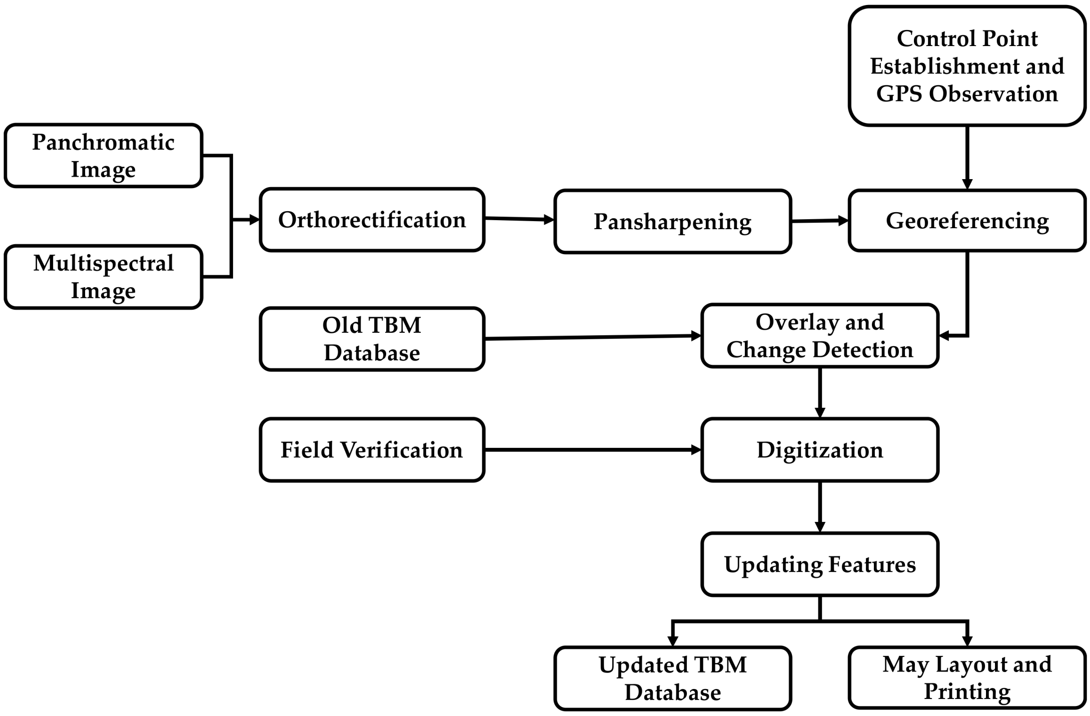


Figure 2. Flow chart of current Topographic Base Maps (TBM) database update adopted by the Survey Department of Nepal.

An Advanced Land Observing Satellite-1 (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) Digital Elevation Model (DEM) of 12.5 m was used for the orthorectification of the images. After orthorectification, the multispectral image was pan-sharpened to get a resolution of 2 m. After that, georeferencing was done. The validation of orthoimage was done by calculating a root-mean-square error (RMSE) for a spatial accuracy equivalent to the size of a pixel (ground sample distance) in the output image.

After that, the missing elements were incorporated in updated maps through image analysis and field verification. During field verification, the administrative boundaries were verified with the help of the public representative of every local unit, and changes in the data were well documented and acquired using handheld GPS units.

The changes were detected, and the digitization of the changes in topography was accomplished. The updating of a topographic area was done as accurately and elaborately as possible. The configuration of the matters that were to be delineated on a topographic map was projected into an orthographic delineation as observed from above. If the same matters that were supposed to be delineated in a topographic map vertically overlapped, then those that were lower were not delineated except for those for which symbols were delineated. Regarding the matters that were delineated by symbols, the tolerable error in horizontal movement of their position was + 0.25 mm from the actual dimension may be permitted for unavoidable ones. After change detection and digitization, edge matching was done to make the database seamless so that features at the border of the map sheet were connected. The spatial data consistency with the real world was checked through field visits. The quality of digitized data was checked by using the data reviewer. Another logical checking was performed using the specifications of the data model, such as format specification, topological constraints, the uniqueness of identifiers, and domains of attribute values.

2.3. Issues in Present Practices

The first phase of the current TBM database update faced a lot of challenges. The planning needed for the update was not systematic, and inadequate before field visit assignment. Due to a lack of prior decisions for choosing the methods of TBM updates, the work was repeated. The feature extraction from the image should be done before the field visit, but, in this case, the situation was the opposite, which caused difficulty in recognizing some features in the image. Due to the inadequate training for the available human resources, progress was very slow. The work was expected to be completed in five months but took around a year. Some professionals did not have knowledge of GIS and RS, which made the task more tedious.

A lack of computers of good processing speed was also one of the factors making the work slow. Powerful GIS software packages were not fully exploited, and the word was limited to cartographic digital databases. Furthermore, the RS section needs to keep pace with technological advancement and to adapt to changes in terms of hardware and application software. The current practice of the TBM update was labor-intensive and time-consuming, as it took more than eight months to update 22 sheets of TBM by seven teams with six members in each team. As a result, maps were already outdated when the first phase was completed. This was the major issue in present updates. Developed countries like Great Britain [21] have the provision of a map currency audit, in which every six months the NMA selects a sample of 4000 areas that are visited by field surveyors and examined for any discrepancies. Any features over six months old that are detected in the field but are not found in the database are recorded, and the results are used to calculate the value of the performance monitor. This system is lacking in Nepal. There is no provision of map currency audits, which makes the update of the map slow and outdated.

A standard protocol or guideline is required for every job. Without a guideline, a goal is hard to achieve. In the first phase, the work was tedious and repetitive. However, it is improving as proper guidelines and standardization are coming together from the experience. Still, the digitization was subjective and there were no proper solutions for technical difficulties faced during the work. Another technical difficulty was creating a full list of symbols for TBM features. Converting a traditional method prepared TBM to a digital method required technical expertise and is still under progress.

Assuring data quality is another key issue for updating imagery. Both currency and logical consistency need to be considered. The former is related to the up-to-dateness of the imagery used and can be validated by a comparison of the data to the real world [22]. The quality control of this topographical update was done manually, so the process was time-consuming. Due to the manual method of quality control, the maps were prone to many human errors. Although all the errors present in the map were checked as per the standards of SD, some minor errors were still prevalent.

Due to the limitation of human senses, digitization and datasets were not fully checked. The significant difficulties for the NMA are to successfully oversee assets (time, prepared cartographers, and financial plan) in order to adjust to innovations, to create adaptable mapping items that are required by a developing assorted variety of clients and applications, and to oversee rivalry from items created by the private part. Nepal is a developing country; mapping has always been supported by foreign bodies. After a long gap, although the current TBM update is being done under the SD, the work is being manually digitalizing over pan-sharpened high-resolution ZY-3 imagery supported by China. Various research works are going on around the work for making the work more automated and efficient. Many countries are following the techniques that are discussed in Section 4.

3. Casework of a TBM Update

The SD of Nepal has been updating TBMs of Nepal. This paper presents the procedure and issues that appeared while updating a TBM sheet (2782-03D) titled the Lalmatiya of the Dang district.

3.1. Casework

Topomap sheet 2782-03D covers most of the area of the Dang district and some parts of the Kapilvastu district (Figure 3). It covers an area of 50 km^2. This sheet covers the most developing area of the Dang district, Lalmatiya, which lies in the Gadhawa Rural municipality. Big irrigation projects are running in this region. It is the major agricultural hub of the Dang district. Recently, many developmental works have been done in Gadhawa. This area's elevation covered by this sheet ranges from 250 to 750 m. Rapti River, which passes from east to west, lies in the center of this area. Some of Hulaki Highway also passes through this area, including Bhalubang, a bazaar situated at the Terai/Hill interface that is now a junction on the east-west Mahendra Highway where branch roads served by scheduled buses go to the Pyuthan and Rolpa districts.

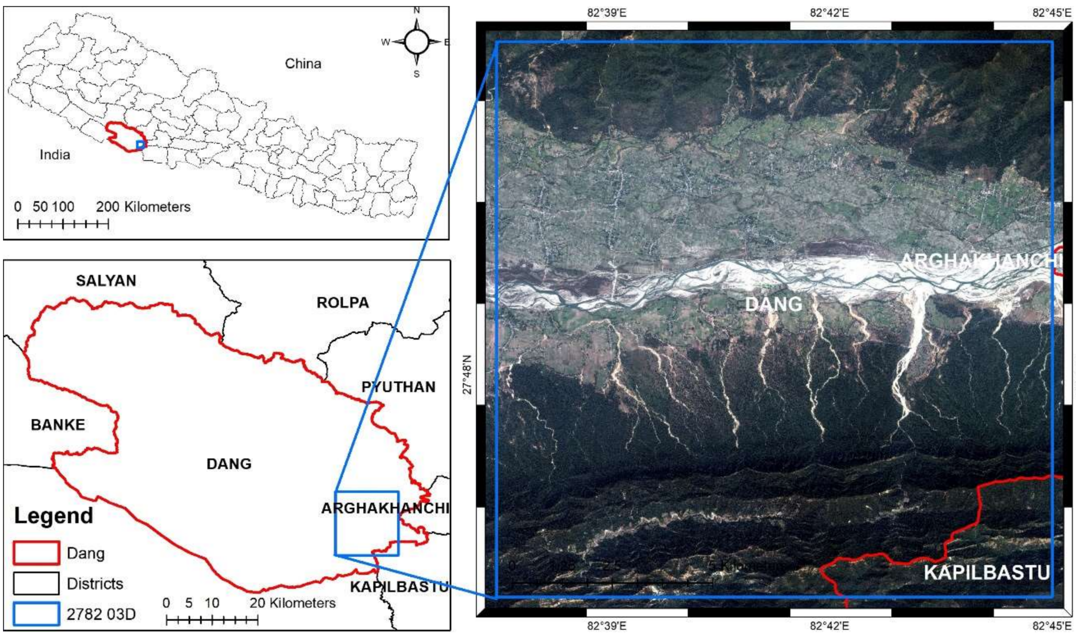


Figure 3. Location of the Dang district and the TBM sheet number 2782-03D.

3.2. Materials and Methodology

The original TBM database was obtained from the GIID. These data were overlaid on the top of the georeferenced ZY-3 images, and the changes were detected and digitized. This work was done in the first phase of the latest TBM database update. The field visit was done between March 2018 and May 2019. Change in landcover and features were updated using the imagery and issues were resolved in the field using handheld GPS units.

While doing fieldwork, help from local authorities was taken for a collection of feature details. It was difficult to get help when they were busy with public affairs. Without official and elderly personnel, it was difficult to collect historical, cultural, political, economic, and administrative detail in the local area without some being missed. In some cases, when the local people were unable to understand the technical words, the work was also interrupted. During the field verification of the local unit boundary, there was a conflict between local authorities related to the boundary. The boundaries of local units of Nepal are demarcated based on natural features, e.g., rivers, ridges, and valleys. The course of rivers has changed with time, so the boundary has also changed; however, the local people have been following the old boundary, thus causing conflict. The solution to this problem was to have a discussion with the representative of a local authority and to solve the issue.

During field verification, the category of the road was determined to ease the update of road features. The details in the field were different from the details from the imagery, e.g., a heap of straw in the field could look like a house in the image and so it was separated during field verification, a canal and a road look the same in an image, etc. In the field verification, these things were identified and acquired from the handheld GPS units.

There was a lot of difference in old data and new imagery. The course of the river was shifted dramatically, as shown in Figure 4. The old digital database was prepared by digitizing old maps. Thus, many features were missing in the old database. The TBM update results showed that many more features could be identified on the imagery than could be reliably captured. This indicated that imagery of this resolution could be used to detect changes in the landscape, and these could then be captured using other methods. The advantage of this process is that the data capture was targeted so that only areas of known change needed to be visited. There were too many heavily generalized roads in the old database, so these roads were drawn again, and new roads were updated.

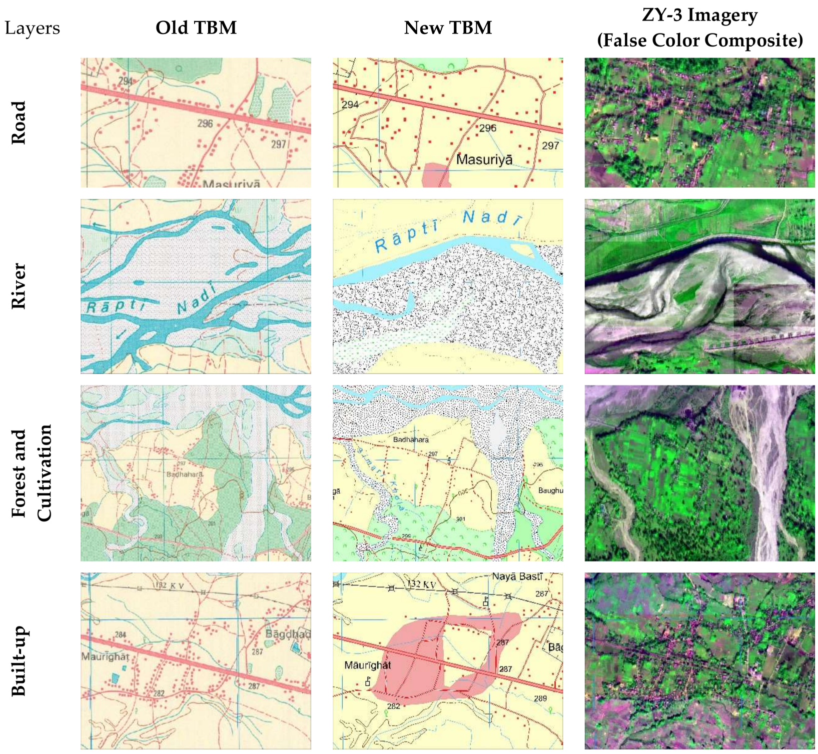


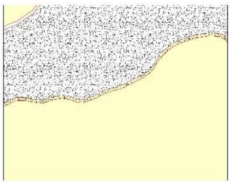
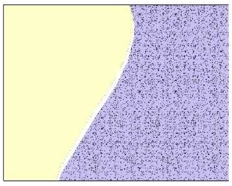
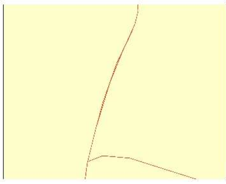
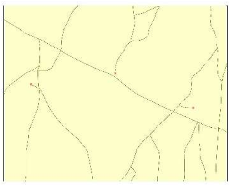
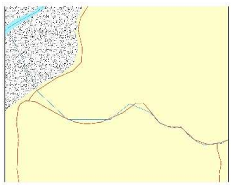
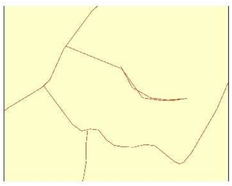
Figure 4. Comparison of the new map with the old map, as well as a pansharpened image from satellite ZY-3 of November 2018 for various features.

After change detection and digitization, topological and manual errors were detected and solved semi-automatically. The topological errors included gaps in the polygons, overlaps in the polygons, overlap in lines, self-overlap, overlap between hydro lines and trans lines, and dangles in lines, etc. as shown in Table 1. Quality control for the topological errors in the updated database was done using the Data Reviewer tool. The quality assessment team manually checked the consistency and validity of the prepared database. In the process, the following aspects of data quality were checked:

(a) Individual image files were in the correct format.
(b) Specified coordinate system.

(c) Accurate georeferencing.
(d) Complete coverage.
(e) Color balancing.
(f) Edge matching.
(g) Size of image pixels matches the data product specification.

Table 1. Few samples and conditions of errors associated with digitization.

S.No.	Sample of Error	Condition
1		Overlapping of a polygon.
2		Silver: Gap in a polygon.
3		Overlapping of lines.
4		Dangles: Overshoot and undershoot in lines.
5		Overlapping of hydro lines and transportation lines.
6		Self-overlapping.

3.3. Result

After checking the quality of the obtained datasets, the final compilation was done. The map was compiled in the standard template prepared by the SD. The categories of symbols used in the compilation were prepared according to the standard of the SD of Nepal. Finally, that compiled map was exported in the Cyan, Magenta, Yellow, and Black (CMYK) color format and printed with a CMYK color printer. The color pattern was slightly changed from the original map to make it more visually appealing. The contents in the template and symbology were modified from the previous template (Figure 5). Due to the emergence of federalism in Nepal, local boundaries have been changed. Multiple village development committees were merged to be a rural municipality and an urban municipality. There were many major changes in that TBM sheet. The names of some rivers and settlement areas were also updated. During the field visit, the features that were not identified in the images were identified and updated.

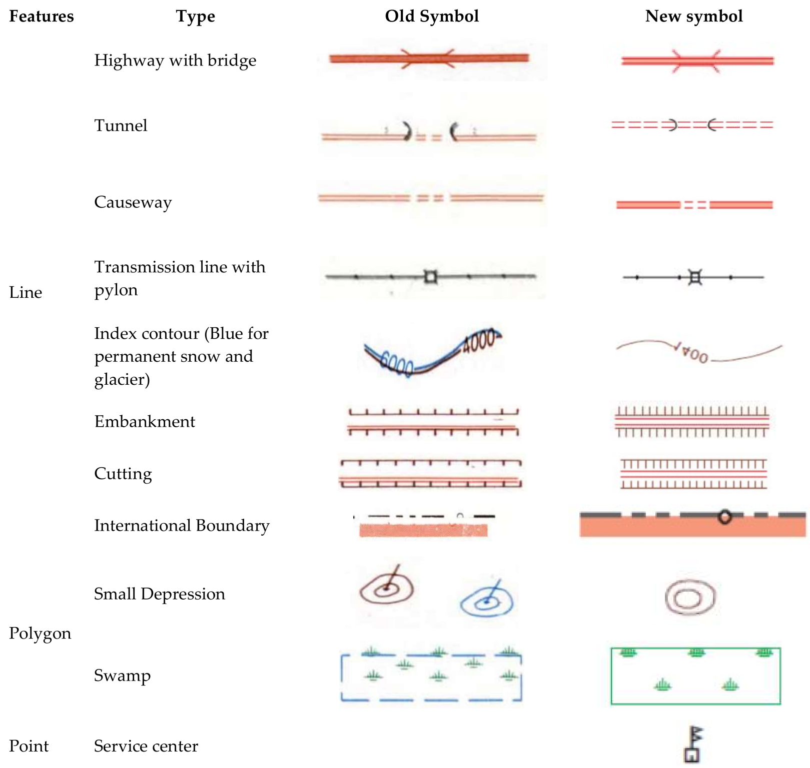


Figure 5. The comparison of symbology in old and new TBMs.

From the result obtained, there were many changes seen on the map. There were a lot of changes in the landcover. In the old map sheet, one house symbol was used for one house in the imagery. However, in the new map, the houses were generalized. If there were many houses in the large area, then they were converted to a built-up area; otherwise, they were generalized to make the map clear and concise. Consequently, there were many built-up areas added to the land cover. On the hilly side, the forest area was converted to cultivation areas. The course of the river was also changed as the maps were not digitized for so many years The temporary brick kilns were removed from the database because of the government's policy of removing all the brick kilns that were made before the earthquake. From the result of the topographic map update, we could see some of the forest areas have been changed to the cultivation area, which indicates that people have been cutting the trees for making land for agriculture for many years. Additionally, there has been a vast increase in built-up areas, thus indicating the growth of the population. The number of industries and factories has also been increased. The increase in population has resulted in an increase in interest in crop production, which has led to the conversion of grasslands to croplands. New irrigation projects in the Sisahaniya area have caused an increase in canals in that area. Forest and grasslands have been changed to agriculture and settlements. Many small road tracks have been changed to big vehicle roads. Many new bridges have been built. The postal highway of that area was paved in the new map. Many roads, temples, and schools have been constructed, and the topography of some areas has been changed due to the earthquake. According to recent studies, the Gorkha earthquake changed the shape of the Earth—literally—by raising and sliding landscapes by several meters [23,24]. Due to earthquake-induced landslides, there have been a lot of changes in the topography. Figure A1 shows the old topographic map, based on which the new map was updated; meanwhile, Figure A2 of a new updated topographic map of map sheet 2782-03D.

4. Discussion

Nowadays, the updating and maintenance of TBMs at so many scales have become difficult tasks faced by the NMA. In the past, maps at each scale were updated separately. Though the process followed by the SD for TBM updates is accurate due to the use of high-resolution satellite imagery, it is labor-intensive and costly. Field varication, digitization, and map compilation require skilled manpower and a huge budget, which makes the process slow and expensive. The major issues in our current work were inadequate training for survey professionals, powerful computers, and software. These can be solved by giving training to the professionals before the start of the work with sample data of various cases. Recruiting temporary staff in a contract can minimize a shortage of manpower and delay in works. Giving priority to open source software can also help to solve the issue of software. Buying powerful desktops with good computing and graphics quality with a large dual-screen can help a professional in achieving a better result. Allocating the budget for the research works allows new technologies to be introduced into the SD to make it work better. For the currency of updating work, an automated landcover change detection process should be carried out every six months using free available or open-source satellite images. Survey professionals should be allocated to carry out field visits to check the changes and amend them so that a certain threshold of change could call for the TBM database update of the region.

To meet the requirement for rapid updating, the procedure can be changed to automated change detection and quality control. Many countries are following the automated process of change detection and quality control, which makes their update works fast and timely. Zhang et al. proposed the technique of map updating based on map conflation technology. Map conflation is the process of creating a new database based on two or more different databases covering the same area [25]. The new database is superior to any single one in the whole, with high accuracy, rich attribute information, up-to-dateness, etc. This proposed methodology was tested by updating the Canadian NTDB based on road extraction from remotely sensed imagery in 2003 AD. This technique is very useful in cases where the improvement of the positional accuracy of the original version of the database is necessary or desired. Many researchers are working on producing maps by applying the automated process of feature extraction. Many countries are shifting to artificial intelligence (AI) technologies for feature extraction [26–30]. Map fusion technologies are also used for feature extraction.

Chunsun and Zhang [31] presented the practical automated road extraction from stereo aerial images. The system has several advantages over other approaches. It uses existing knowledge, image context, rules, and models to restrict the search space, and it treats each road sub class differently while checking the feasibility of multiple possible hypotheses, therefore providing reliable results. The system contains a set of data processing tools to extract various cues about road existence, and it fuses multiple cues and existing information sources. Olsen et al. [32] presented a change detection procedure that is a classification-based method using the existing object registrations in the map database as training areas to determine the characteristics of the different classes (in this case, buildings). The method was evaluated on building registrations from the Danish Topographical map database (TOP10DK) in combination with Red Green Blue (RGB) (color) and Color-Infrared (CIR) aerial photos [33]. The Abu Dhabi municipal system used mobile LiDAR (light detection and ranging) technology to update base maps by using daily transaction services. It used and integrated the mobile LiDAR technology into the municipality's daily workflow such that it became the standard cost-efficient operating procedure for updating the base-map in the Abu Dhabi Municipal System [34]. Awrangjeb [35] presented a Graphical User Interface (GUI) developed to support the creation of a building database from building footprints automatically extracted from LiDAR point cloud data. An automatic building change detection technique by which buildings were automatically extracted from newly available LiDAR point cloud data and compared to those within an existing building database was then presented.

A developed GUI helped a user to quickly examine each suggested change and indicate his/her decision to update the database. According to the Ministry of Finance, the Government of Nepal is starting a pilot project of making elevation maps using LiDAR technology with the support of the JICA. LiDAR technology is the most promising technology for topographical mapping and elevation mapping. LiDAR technology helps to capture data with high accuracy. LiDAR uses an active illumination sensor and can be collected day or night when compared to traditional photogrammetric techniques [36]. Elevation data are collected in a dense forest, where photogrammetry fails to reveal accurate terrain surface due to dense canopy cover. Thus, it is better to use LiDAR technology instead of traditional photogrammetric technology for topographical mapping with higher accuracy.

The use of Volunteered Geographic Information (VGI) for TBM updating is also trending in the world. Though it needs to be seriously investigated and responsibly implemented, it has several advantages, such as providing a regular update because it is prepared by volunteers and being cost-effective [37–39]. The United States Geological Survey first used VGI technology to update national maps. It provided complete structured data to the national maps [39].

In Nepal, the mapping and updating of topographic objects using remote sensing are still mainly based on visual interpretation and manual digitizing. The updating of map databases requires time-consuming work for human operators to search for changed objects and to digitize these changes. By learning from those international practices in the future, TBMs can be updated using automated tools for digitizing. The SD can make is own automated tools for change detection and mapping. Using new technologies like LiDAR technology for data capturing also helps in mapping and updating maps with high accuracy and a low cost. From laser scanning technology, the accuracy of up to 90% classification can be achieved [40]. In the future, these new technologies and methods will enhance the updating and mapping procedure. To improve the change detection and mapping of TBMs, new and advanced technologies should be developed, and focus should be given for solving these issues. A real-time updating system should be developed by the SD to make maps consistent with the real world. The SD also can make use of VGI in map updating. VGI helps get a timely update of maps at a low cost.

Deep learning and AI technology have been studied by many researchers for applying to change detection and feature extraction processes. Deep learning used with Unmanned Aerial Vehicle (UAV) imagery has arisen as a promising set of technologies for the current demands due to its excellent capabilities for learning high-level representations from raw sensor data. UAVs, being of low cost and low weight, is being utilized for mapping purposes. Due to the low height of UAVs, their resolution is high, which helps to produce better maps on a large scale [41].

5. Conclusions

Being a developing nation, an up-to-date TBM database is important for Nepal. However, current TBMs distributed by the SD of Nepal were prepared during 1992–2001 AD with the support of the governments of Finland and Japan. Though there is a policy of updating of TBM of Nepal every 10 years, this has not been possible because of various factors like a lack of resources. Currently, with the support of the Chinese government, the SD is updating the TBMs of Nepal by digitizing very high-resolution imagery from the ZY-3 satellite. Despite various issues, various levels of data quality control have been applied to ensure a high-quality database, and the first phase of TBMs has been produced. It was realized that the update procedure was slow, time-consuming, and requires high processing computers and programs, and before-hand training with proper guidelines.

Rapid and systematic updating requires a frequent audit, automated change detection, quality control, the semantic integration of data, and the proper management of databases. Though Nepal is using high-resolution satellite imagery for TBM updates, digitizing and field works are very costly and labor-intensive. A huge number of skilled survey professionals and high computing power of devices are required to complete the task. In learning from various countries, Nepal should also opt for new technologies such as UAVs and LiDAR for surveying, machine/deep learning for feature extraction, and land cover change detection that can be applied to facilitate the frequent updating of TBMs in a short period at an affordable cost—thus maintaining the concurrency and needs of the end-users.

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Appendix A

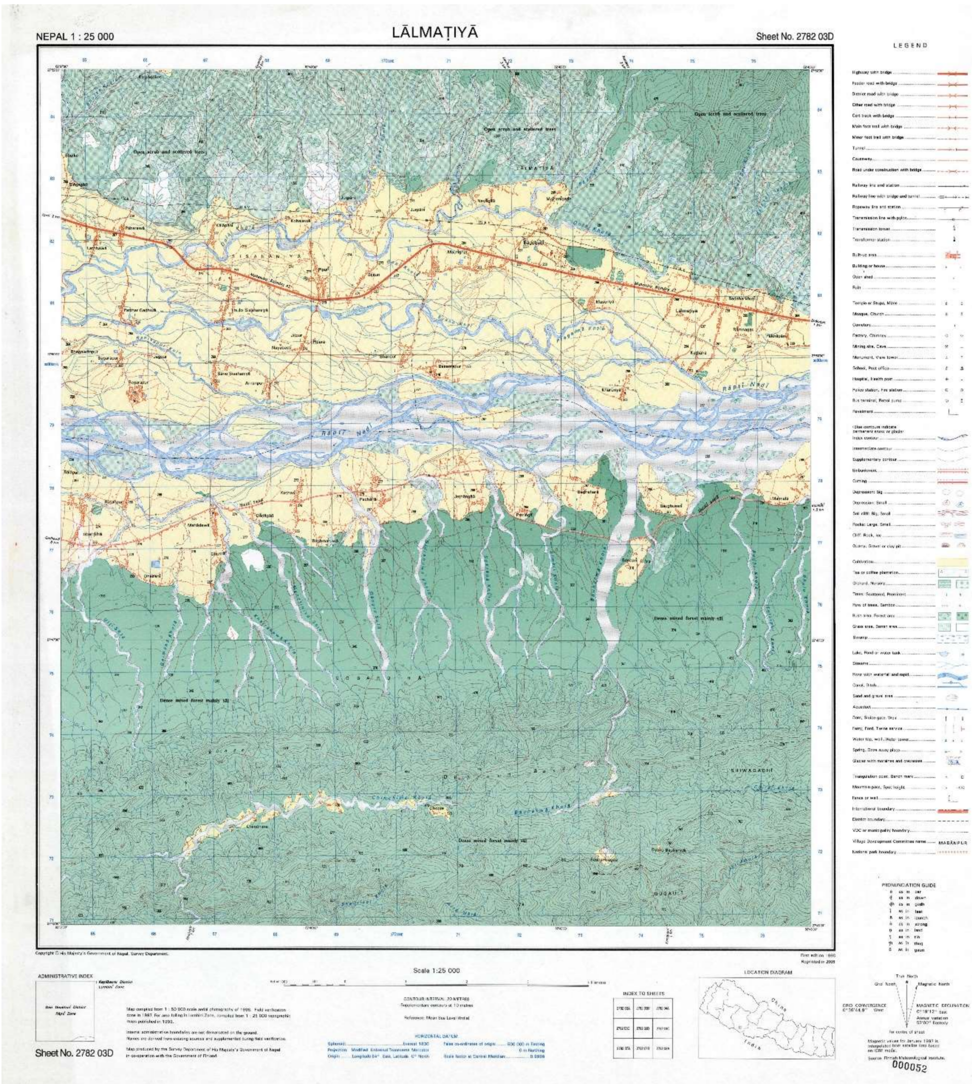

Figure A1. The old TBM of sheet no. 2782-3D.

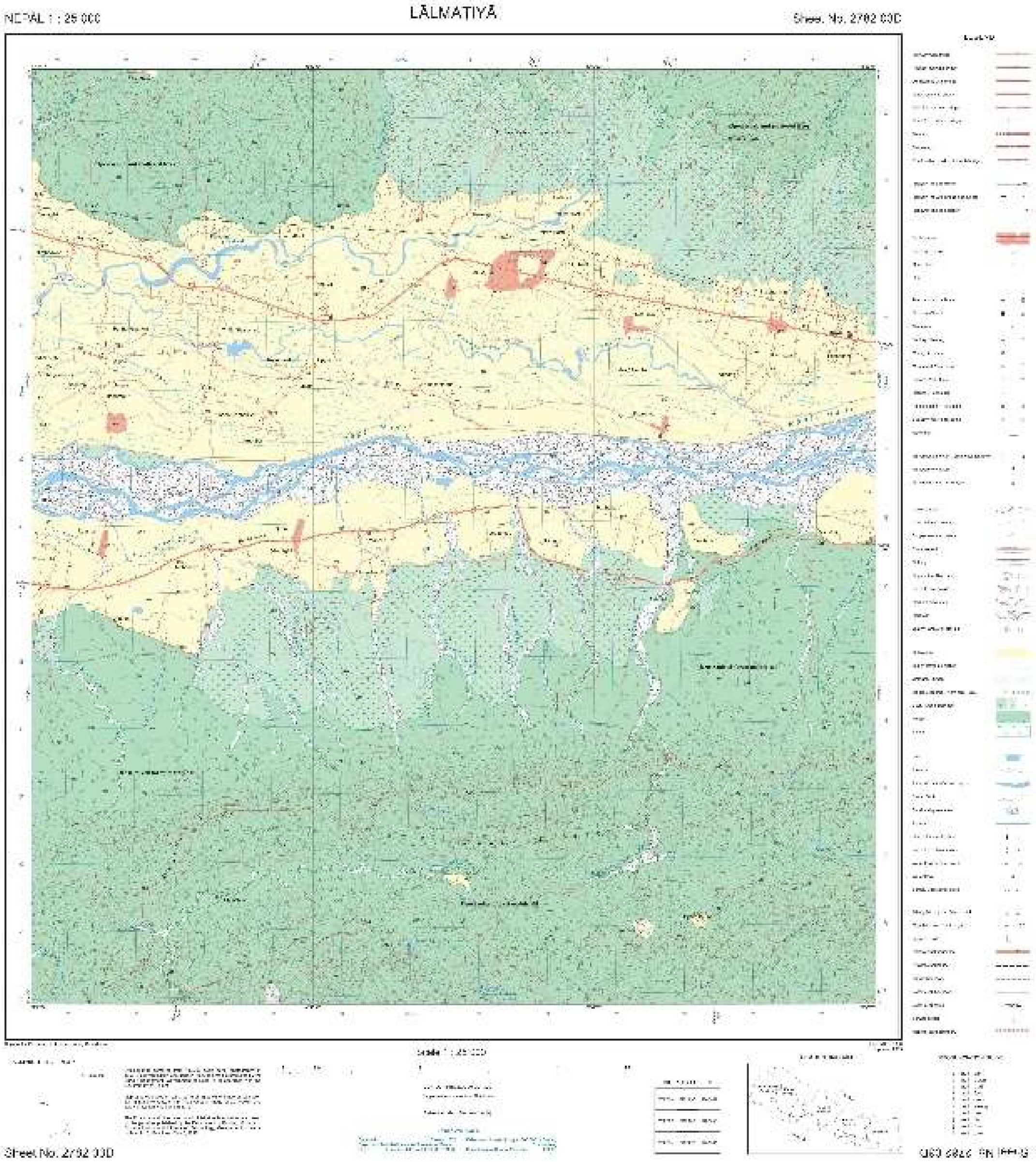

Figure A2. The new TBM of sheet no. 2782-3D.

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