Site Suitability Analysis Report

Bharat Thakkar

Email address: b.thakkar.22@abdn.ac.uk

Student ID: 52214197

1495 UNIVERSITY OF ABERDEEN
OILTHIGH OBAR DHEATHAIN

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Executive Summary

A GIS company has received a contract to perform site suitability analysis to find a best location for a dam in alpine region. The company has performed spatial analysis for projecting and rectifying images, handle DXFs, build models, interpret aerial photo and topographic maps, digitise vectors, optimise decision-making, quantify the landscape change, and synthesise results for the dam location.

INTRODUCTION

The company plans to use reference coordinate system, aerial photographs, identify river streams, analyse elevation data, apply multiple criteria for site selection, digitise dam and reservoir, perform measurements, and identify affected land features at the dam location.

TASKS & RESULTS

1: Projecting the topo map.

A topographic raster ‘242040_topo.TIF’ is first analysed, and the raster was added to ArcMap from ‘Catalog’ after connecting folder to the raster location on file system. Once the raster was loaded in ArcMap, ‘Data Frame Properties’ was opened by right clicking the topographic raster. Further, under ‘Coordinate System’ tab, ‘Monte Mario (Rome) Italy 1’ was selected from Projected Coordinate Systems > National Grids > Italy folder as shown in fig. 1.

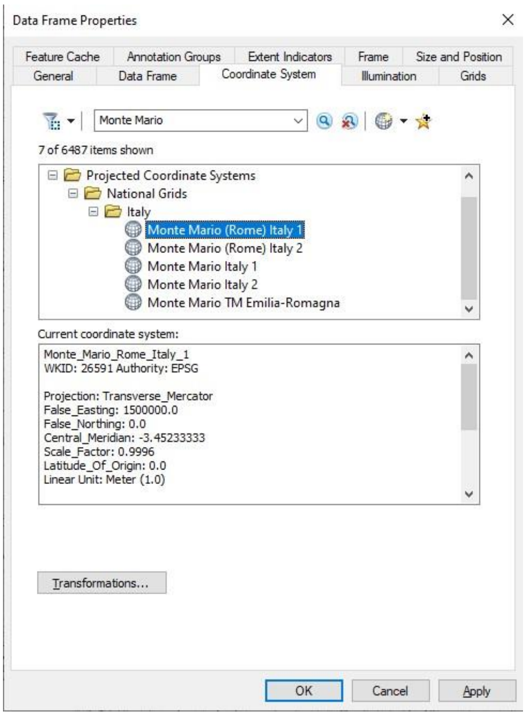


Fig. 1. ‘Monte Mario (Rome) Italy 1’ coordinate system in Data Frame Properties.

2: Rectifying the aerial photo.

An aerial photo of the region is analysed next, and the photo was added to ArcMap from the folder location using ‘Catalog’. Upon adding the photo, a warning was received about having an unknown spatial reference. As the coordinate system of the photo was unknown, georectification of the photo was required by identifying features on the map which aligns with the topographic raster used in task 1. Although, the photograph has low resolution which makes the geographic feature identification difficult, but many features such as edge of a mountain, bend of a road, and corners of a lake shore were used to link 20 control points between the topographic raster and the photo as shown in fig. 2 and fig. 3. Fig. 4 shows the list of control points with total RMS of 2.79785, and fig. 5 shows the topographic map overlaps with the georeferenced photo confirming the alignment between the two.

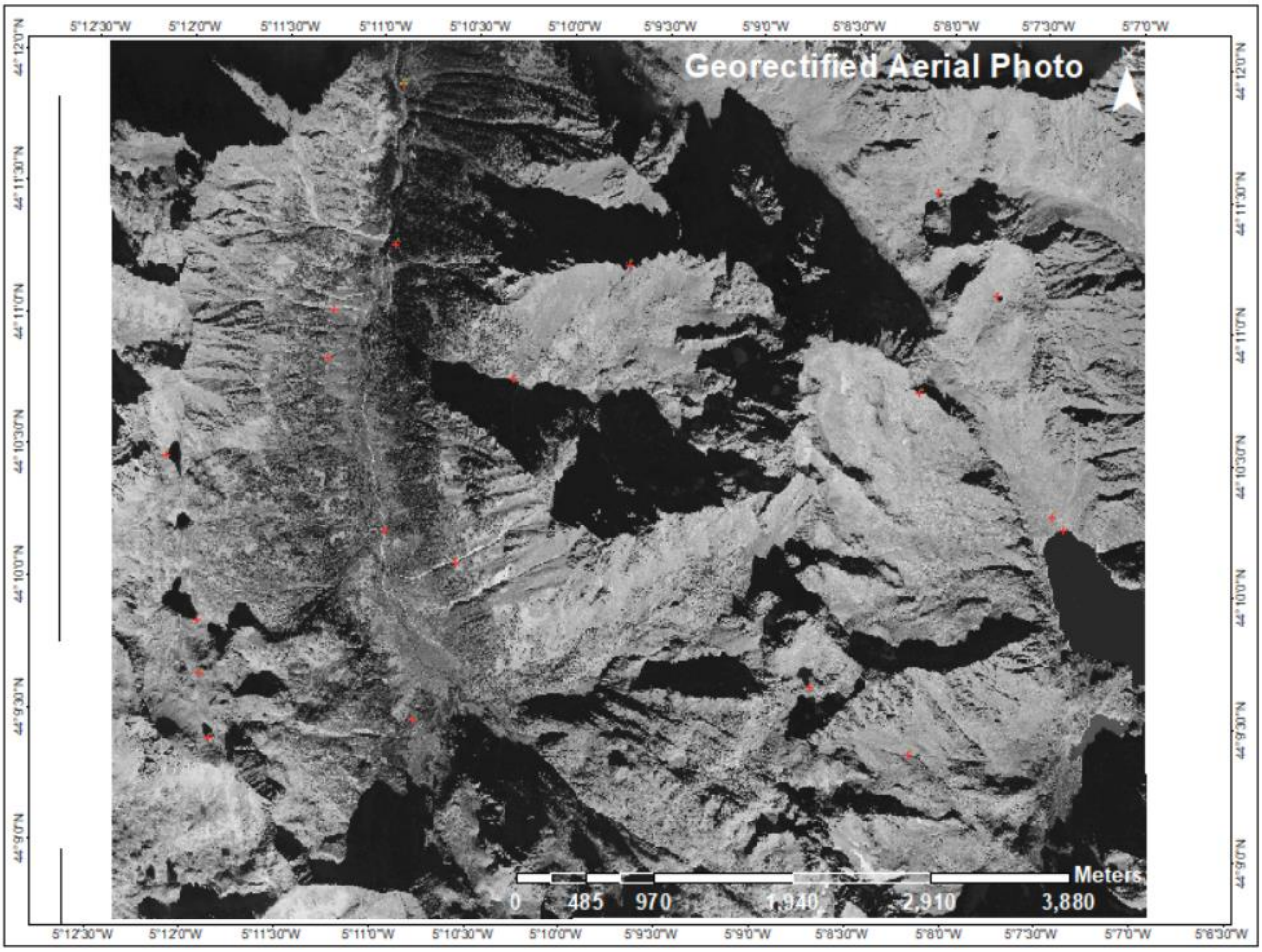


Fig. 2. Georectified Aerial Photo with control points.

Fig. 3. Control Points on Topographic Map.

Link

Total RMS Error: Forward:2.79785

	Link	X Source	Y Source	X Map	Y Map	Residual_x	Residual_y	Residual
☑	1	3.13795185	7.44833391	1361321.8452...	4893837.5352...	0.67240746	-2.46337119	2.55349357
☑	2	3.99814575	2.76771186	1361857.0605...	4890961.0900...	0.19622103	0.14321946	0.24292902
☑	3	1.56200966	3.91115175	1360353.7601...	4891664.6350...	-1.96210279	1.43394190	2.43023388
☑	4	1.21906176	5.79485159	1360142.6288...	4892820.6056...	0.50283806	-1.26128106	1.35782032
☑	5	11.42484966	4.92144476	1366424.4464...	4892287.9148...	-1.29826593	-1.57456514	2.04077187
☑	6	10.68073904	7.58155846	1365963.5983...	4893927.2606...	-0.57859919	1.65808962	1.75614299
☑	7	8.53427758	3.12498823	1364647.9829...	4891182.4024...	-0.75660876	-0.52935579	0.92340368
☑	8	5.16571692	6.64849256	1362570.8840...	4893351.1334...	0.40691452	2.20837083	2.24554696
☑	9	3.06116304	6.89224699	1361274.7269...	4893500.0304...	0.09010621	2.16752678	2.16939888
☑	10	3.93172983	10.02063314	1361808.8520...	4895420.4356...	2.43946864	-2.39695507	3.42000012
☑	11	11.29553990	5.07019497	1366349.3757...	4892381.5577...	3.42759862	0.62133189	3.48345886
☑	12	3.82818571	8.18366365	1361743.7498...	4894288.2325...	-1.34638676	-4.46647118	4.66498897
☑	13	6.49566695	7.94085304	1363386.9127...	4894148.0226...	-0.54866396	3.40877779	3.45265089
☑	14	1.68416291	2.55701016	1360432.3542...	4890830.2527...	-0.34918041	0.04567999	0.35215568
☑	15	4.50204723	4.55033200	1362162.5458...	4892061.0779...	-2.15797386	3.23916696	3.89217854
☑	16	3.68917997	4.91442990	1361662.0193...	4892281.6747...	-1.82035581	0.23980349	1.83608306
☑	17	10.02113710	8.76121163	1365553.2487...	4894652.8075...	-3.33517457	1.81408021	3.79661381
☑	18	9.65896652	2.36533225	1365341.9606...	4890712.8160...	-0.11564778	-3.32738022	3.32938936
☑	19	1.56967645	3.29519048	1360364.5841...	4891284.4666...	3.32984051	0.19449024	3.33551559
☑	20	9.79868357	6.47843181	1365425.8610...	4893245.3896...	3.20356475	-1.15509950	3.40544887

☑ Auto Adjust — Transformation: 1st Order Polynomial (Affine)

☐ Degrees Minutes Seconds — Forward Residual Unit : Unknown

Fig. 4. Control Points in the link table.

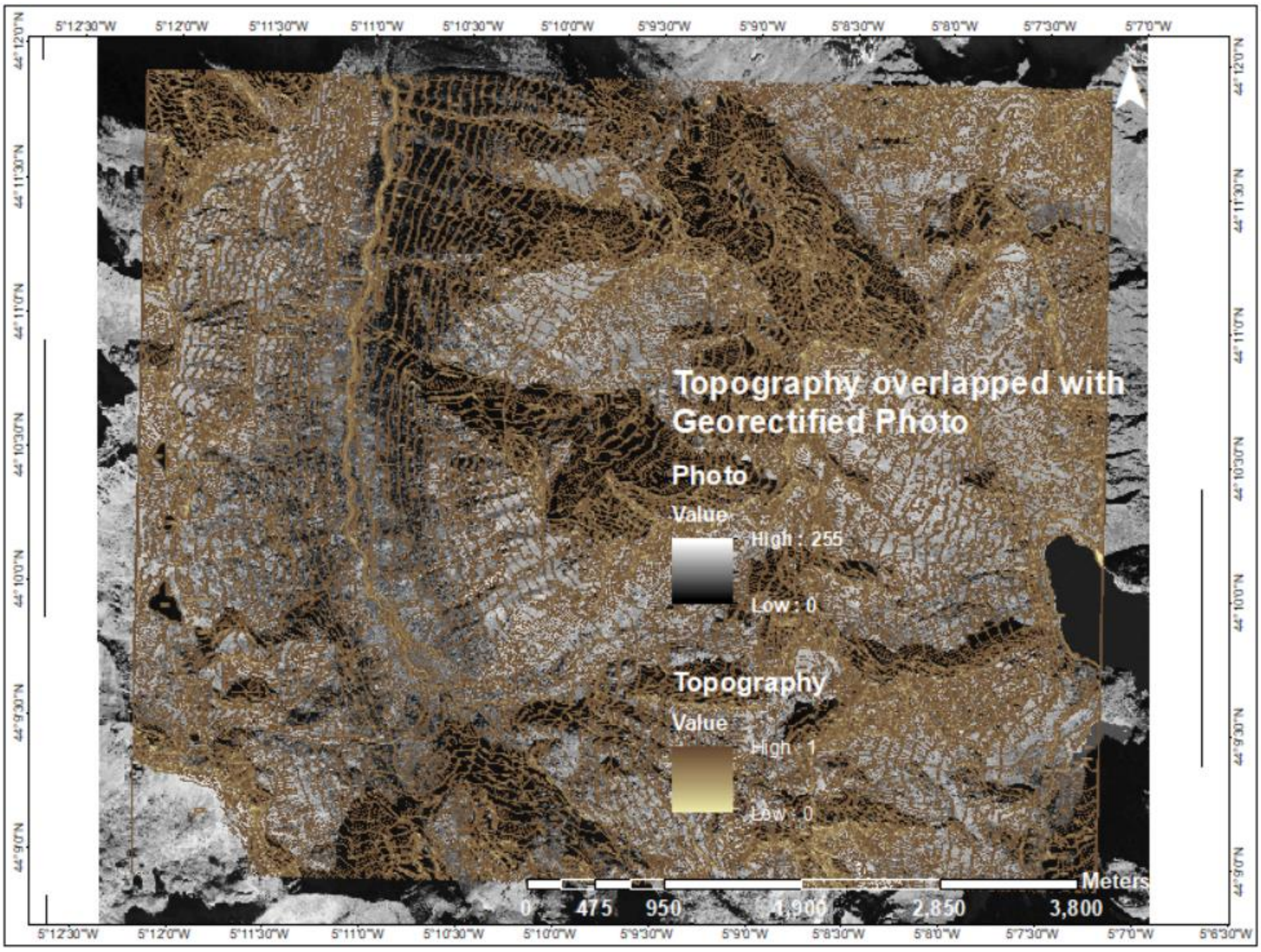


Fig. 5. Topography overlapped with Georectified Photo.

3: Creating DTM for DXF file.

The 242040CU.DXF file is analysed next which has points, polyline and polygons representing elevation of the alpine region. Points represent elevation at specific location, whereas polyline represents elevation as contours around larger area of the map. The points and polyline layers were added to ArcMap from 242040CU.DXF using Catalog. Polyline layer is first cleaned to remove unwanted edges as shown in fig. 6. Next, both points and polylines are used to create Triangulated Irregular Network (TIN) using 'Create TIN' tool (3D Analyst) as shown in fig. 7 and fig. 8. Further, Digital Terrain Model (DTM) is created using TIN as input to 'TIN to Raster' tool as shown in fig. 9 and fig. 10. Important to note that while creating DTM, sampling distance is set to 'CELLSIZE 30' to create 30m DTM.

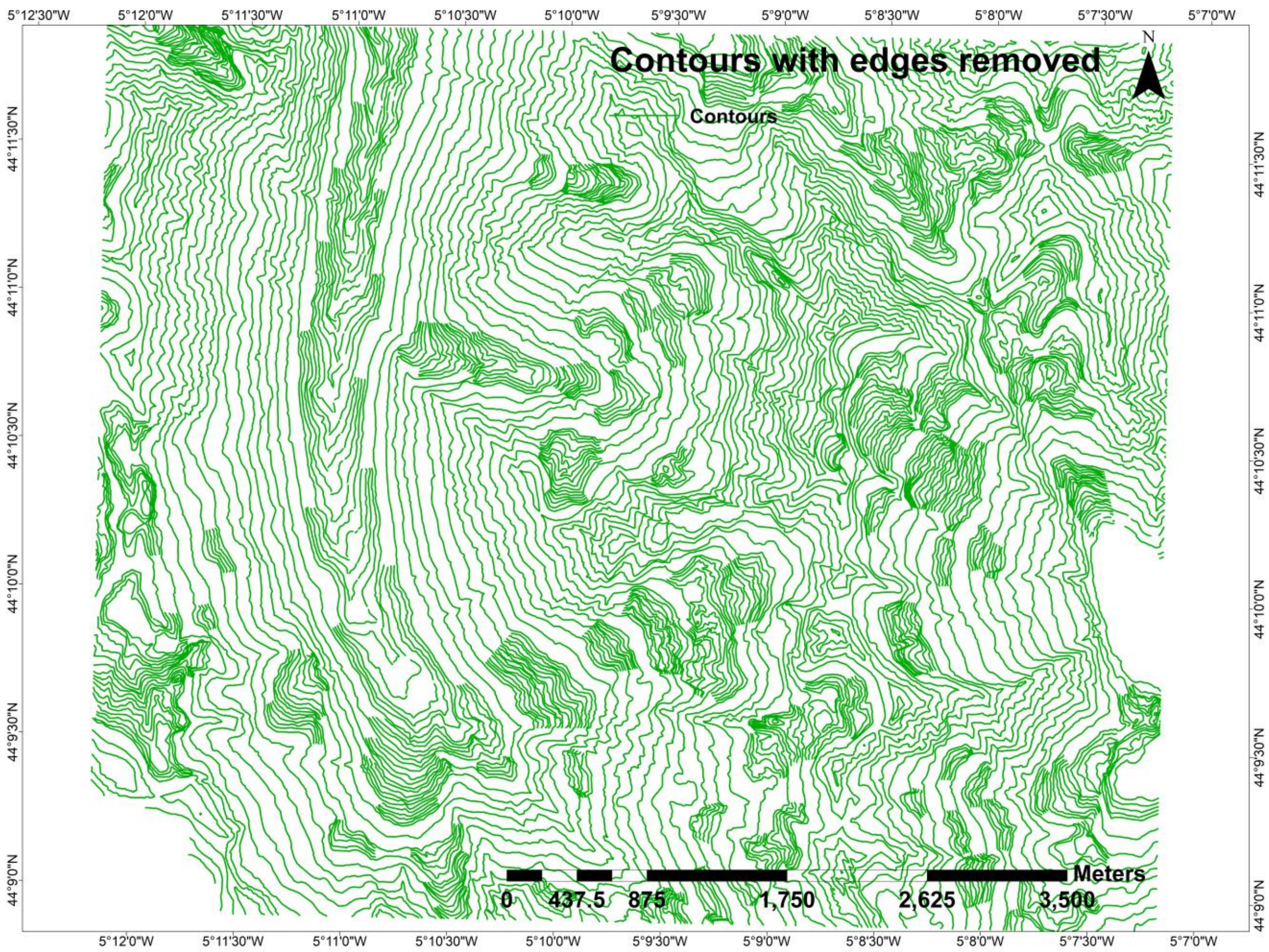


Fig. 6. Polyline contours extracted from 242040CU.DXF and removed unwanted edges.

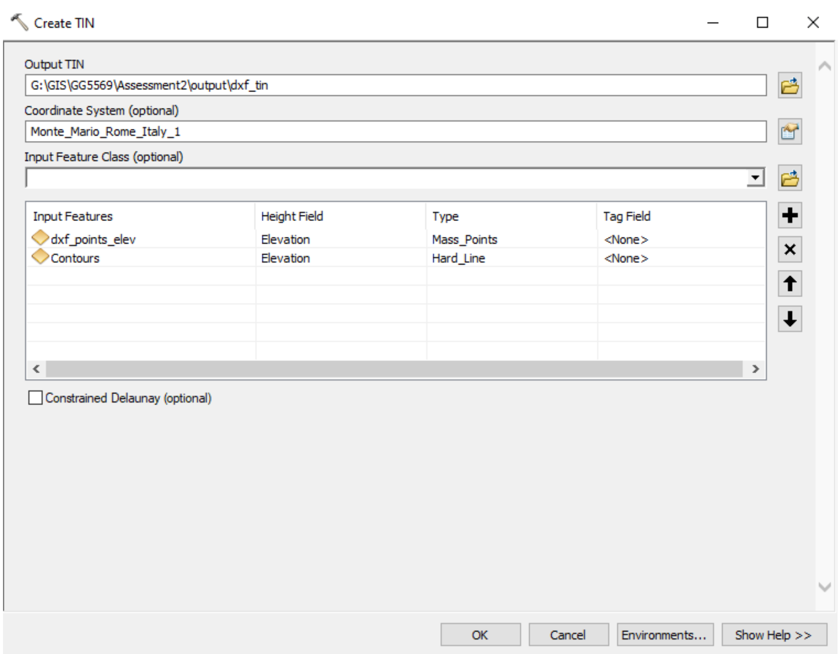


Fig. 7. Using Create TIN tool for generating Triangulated Irregular Network.

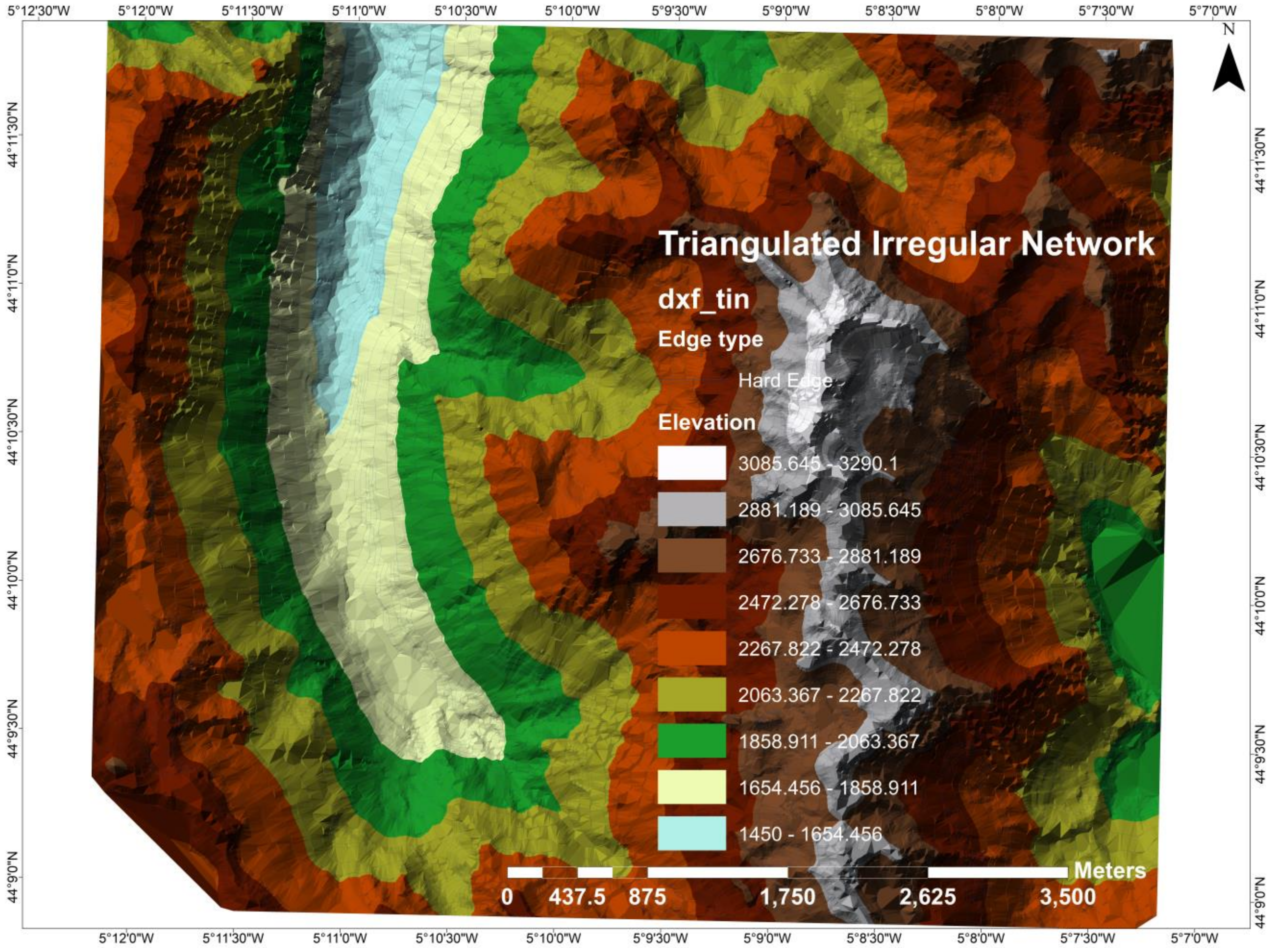


Fig. 8. Triangulated Irregular Network

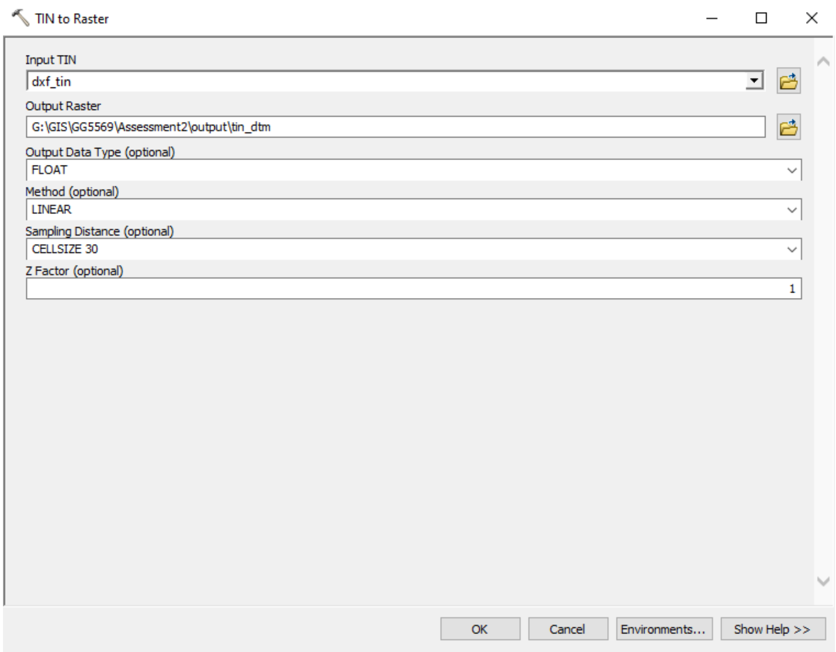


Fig. 9. Creating DTM using TIN to Raster tool.

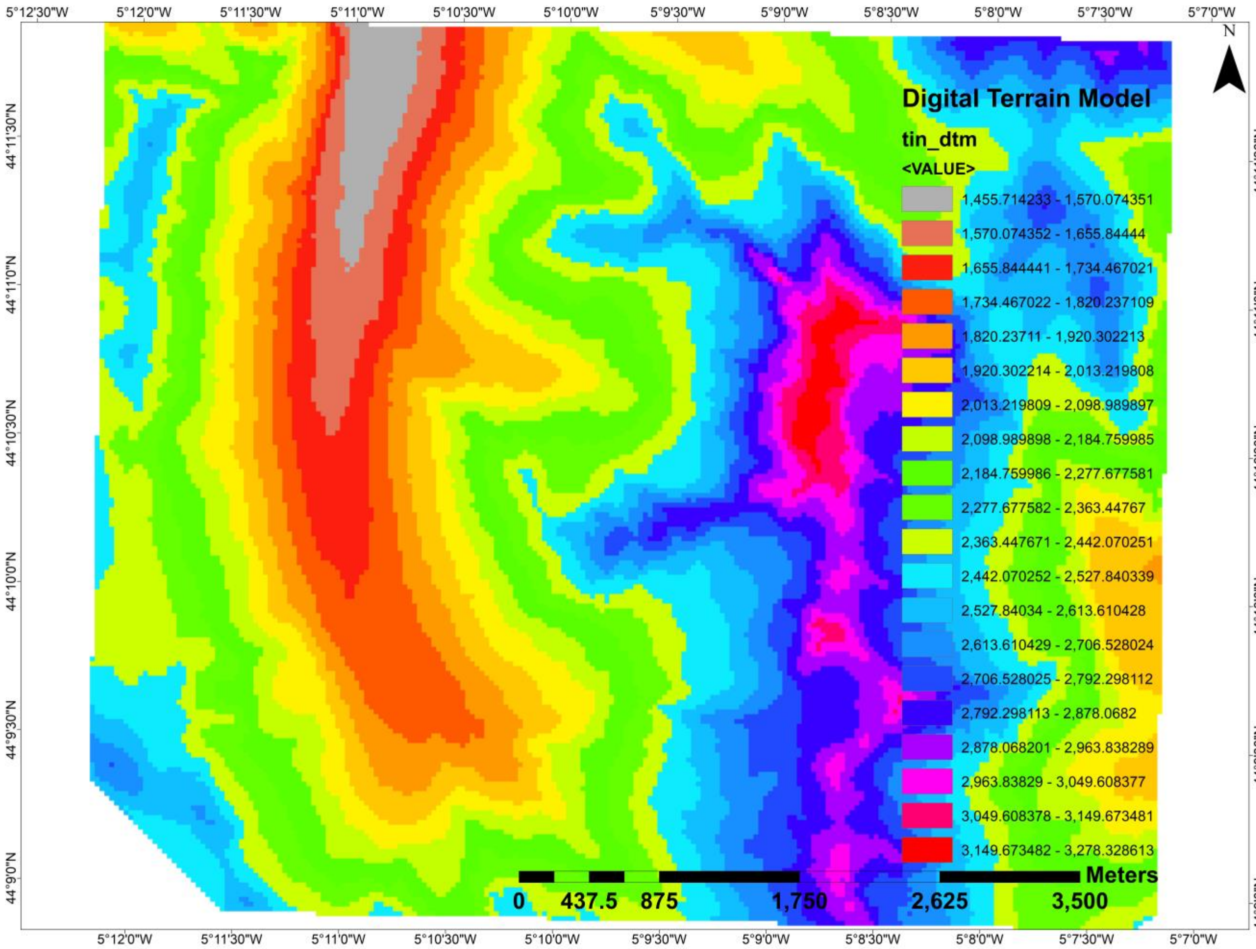


Fig. 10. Digital Terrain Model.

4: Digitising the river/stream system/network

To digitise the rivers in the alpine region, the geo-rectified photo and the topographic map are needed to differentiate between the geographical features of the area, for example, roads must not be confused with a dried river or a stream as roads and river streams are marked differently on the topo layer. Additionally, Google Earth is referenced to confirm geographical features in the area as well. Finally, a shape file of the type of line geometry is created to record lines representing a rivers or streams on the map as shown in fig. 11 and fig. 12. As it can be noticed from the fig. 11, there are four different streams are identified. Most prominent region where streams are identified is on the western part of the map, while few small streams were located on norther-eastern, eastern and central part of the map as well. The stream identified in the west satisfies Strahler's 3rd order as it is connected to other smaller streams, out of which some connects to the water bodies located at higher elevation as well. Also, the western stream geographically runs longer as compared to other streams in the region.

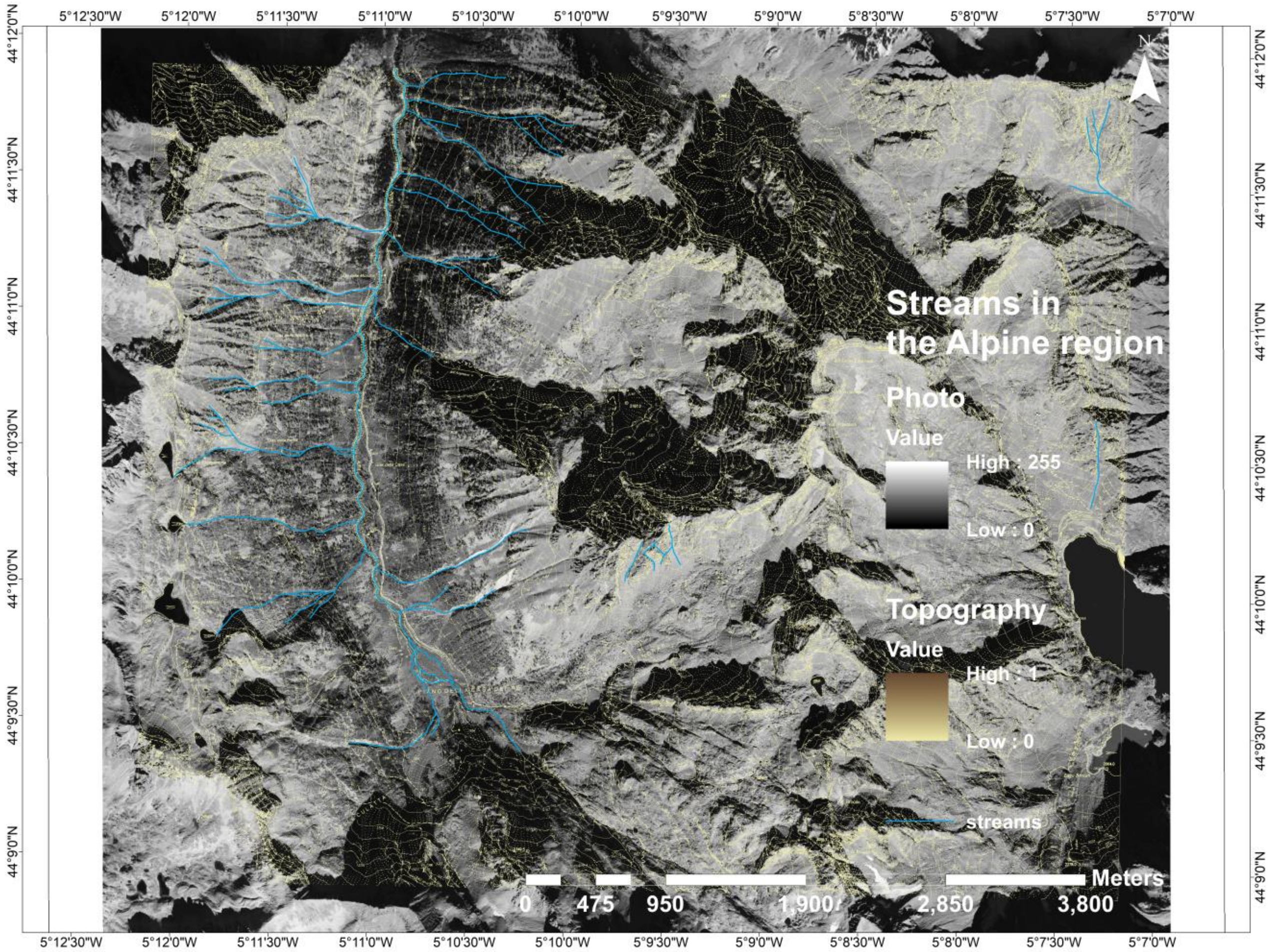


Fig. 11. Streams identified in Alpine region.

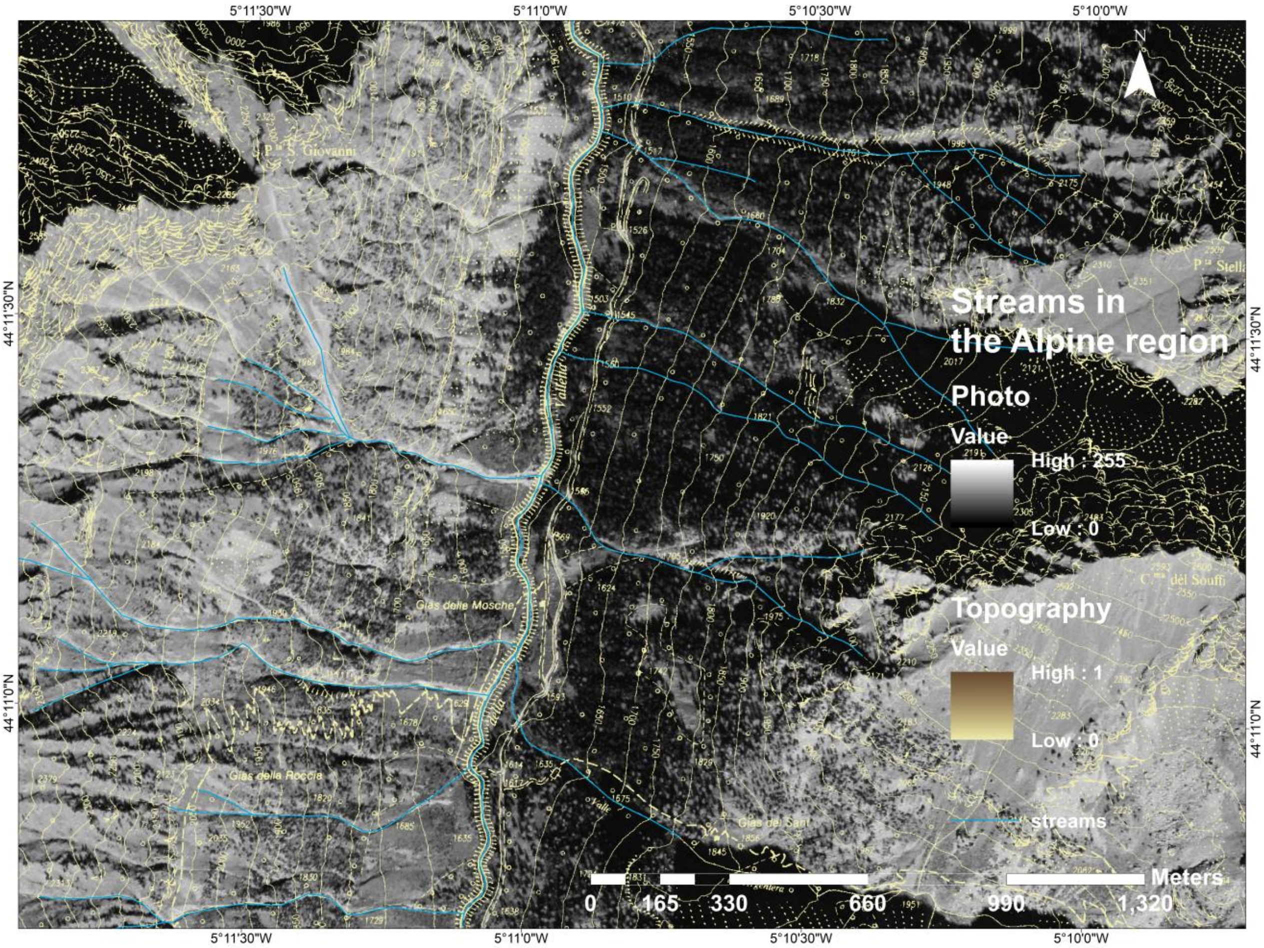


Fig. 12. Streams in Alpine region (Zoomed In)

5: Identifying best location for a dam.

To identify a suitable location for a dam to be constructed, following criteria are considered:

1. Elevation
2. Accessibility for building/maintenance
3. Water accumulation.

1. DTM shown in fig. 10 was used to analyse elevation of each stream. The stream in north-east flows from 2836m to 2256m, stream in the east flows from 2408m to 2080m, stream in central region flows from 2800m to 2504m, and stream in the west flows from around 2384m to 1450m.
2. Further, accessibility to road was considered as a criterion for easy construction and maintenance activity. Stream on the west has accessibility to road through out its length, whereas other streams do not have direct road access.
3. Finally, watershed analysis was performed by using Fill (Fill, 2021), Flow Direction (Flow Direction, 2021), Flow Accumulation (Flow Accumulation, 2021), and Watershed

(Watershed, 2021) tools to confirm maximum water accumulation in the region occurs at the location of the dam as shown in fig. 16. Watershed analysis was not found to be significant at other locations and streams.

Finally, section of the map with lowest elevation below 1500m on western stream was considered ideal for the dam as shown in fig. 13 and fig. 14. Further, to keep height of the dam under 50m and length of the dam to be under 500m, highest elevation point of the dam was identified to be at 1500m contour line and the lowest elevation point to be 1460m above sea level. This resulted in actual height of the dam to be 40m and length of the dam comes out to be 215.28m as shown in fig. 15. It is important to be noted that the location of dam at further lower elevation could not be considered due to road obstruction. Also, the dam could not be lengthier than 215m due to two reasons, one, the dam would have cut across the road, and another, the dam would have been more than 50m in height as well. Thus, the location identified is considered to be the best given the criteria and constraints.

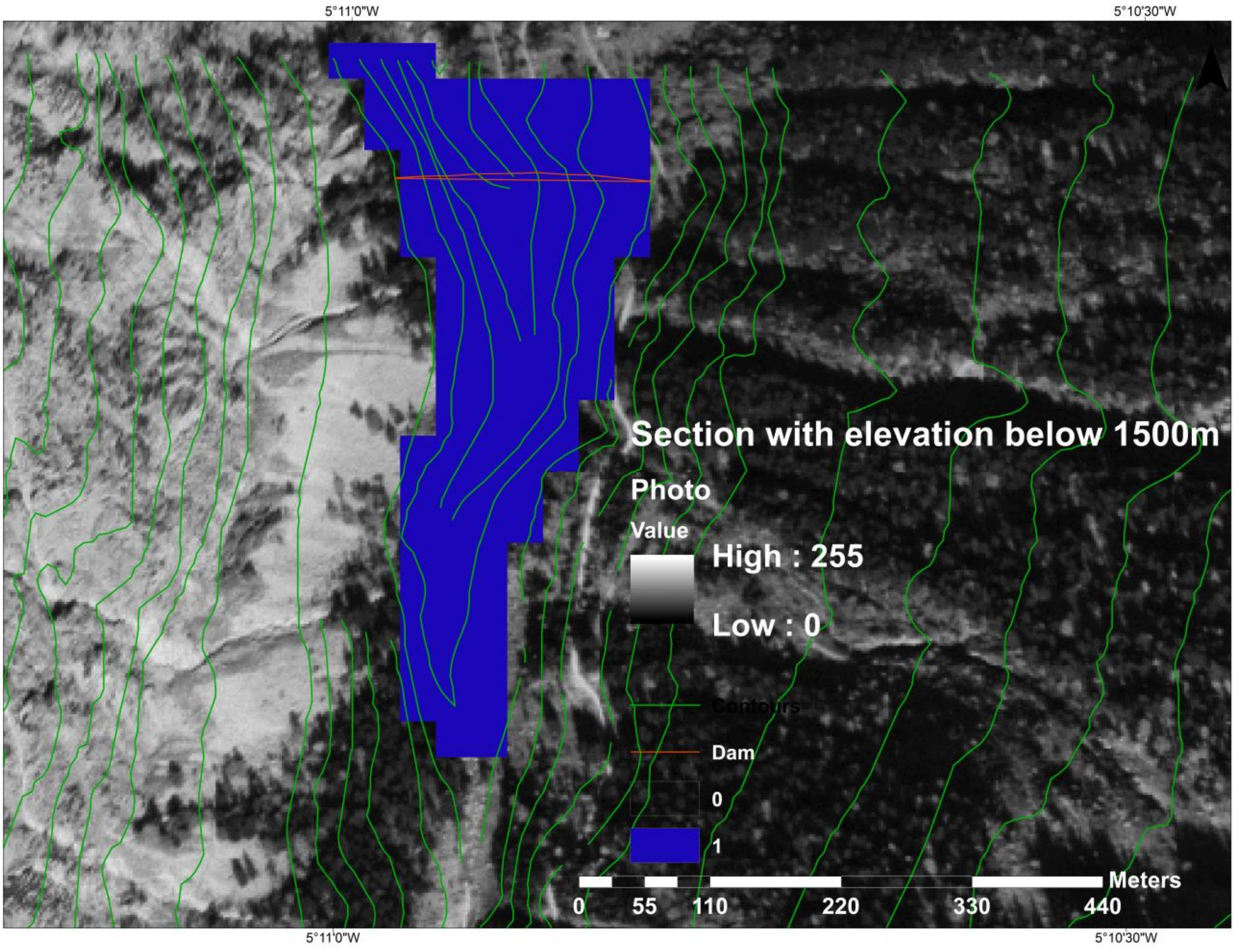


Fig. 13. Section of the map highlighted in blue colour to be lowest elevation suitable for dam.

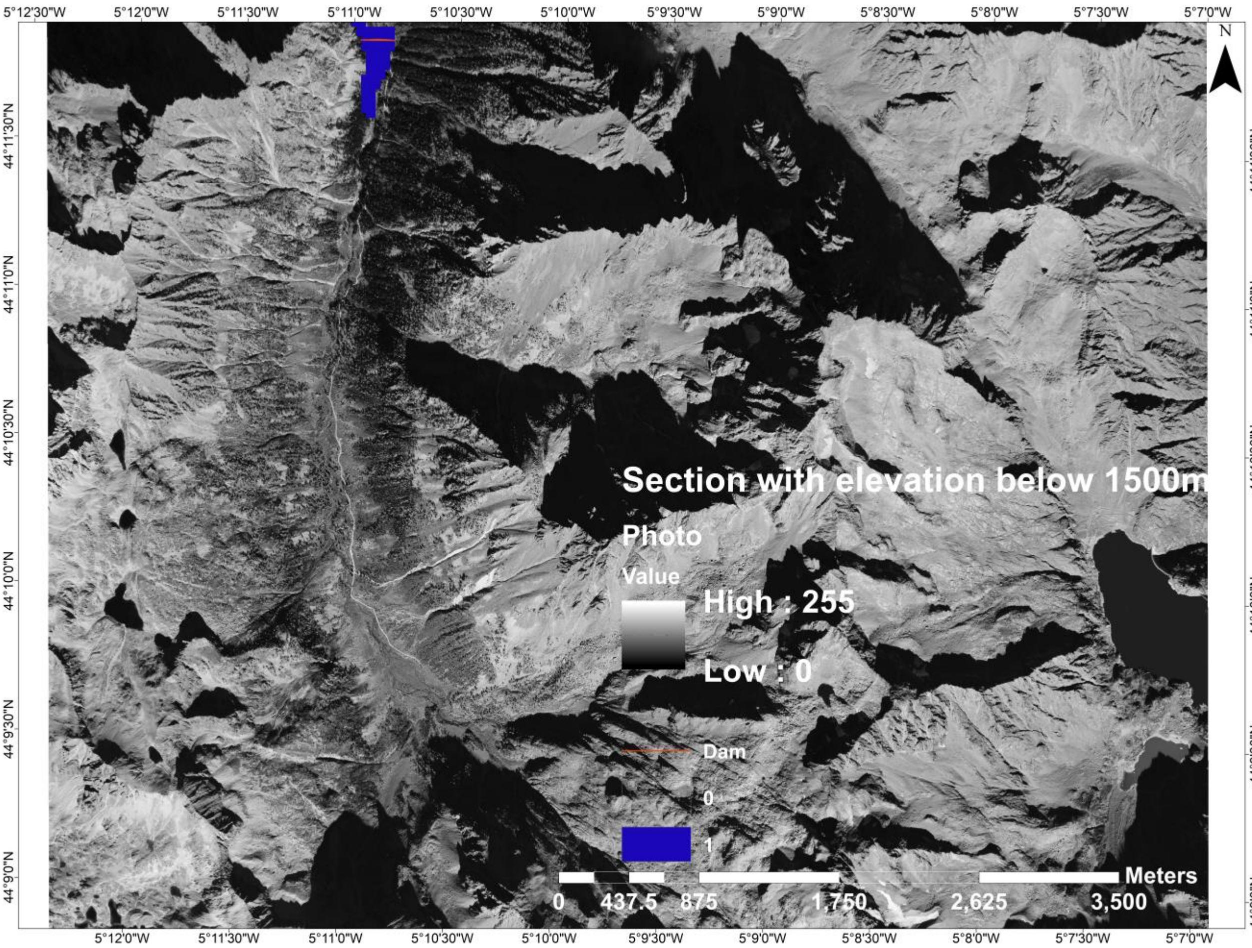


Fig. 14. Section of the map with lowest elevation suitable for dam.

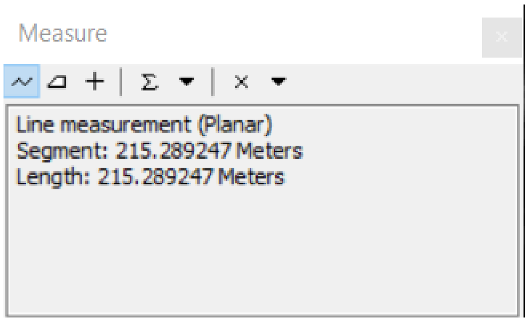


Fig. 15. Length of the dam measured in meters.

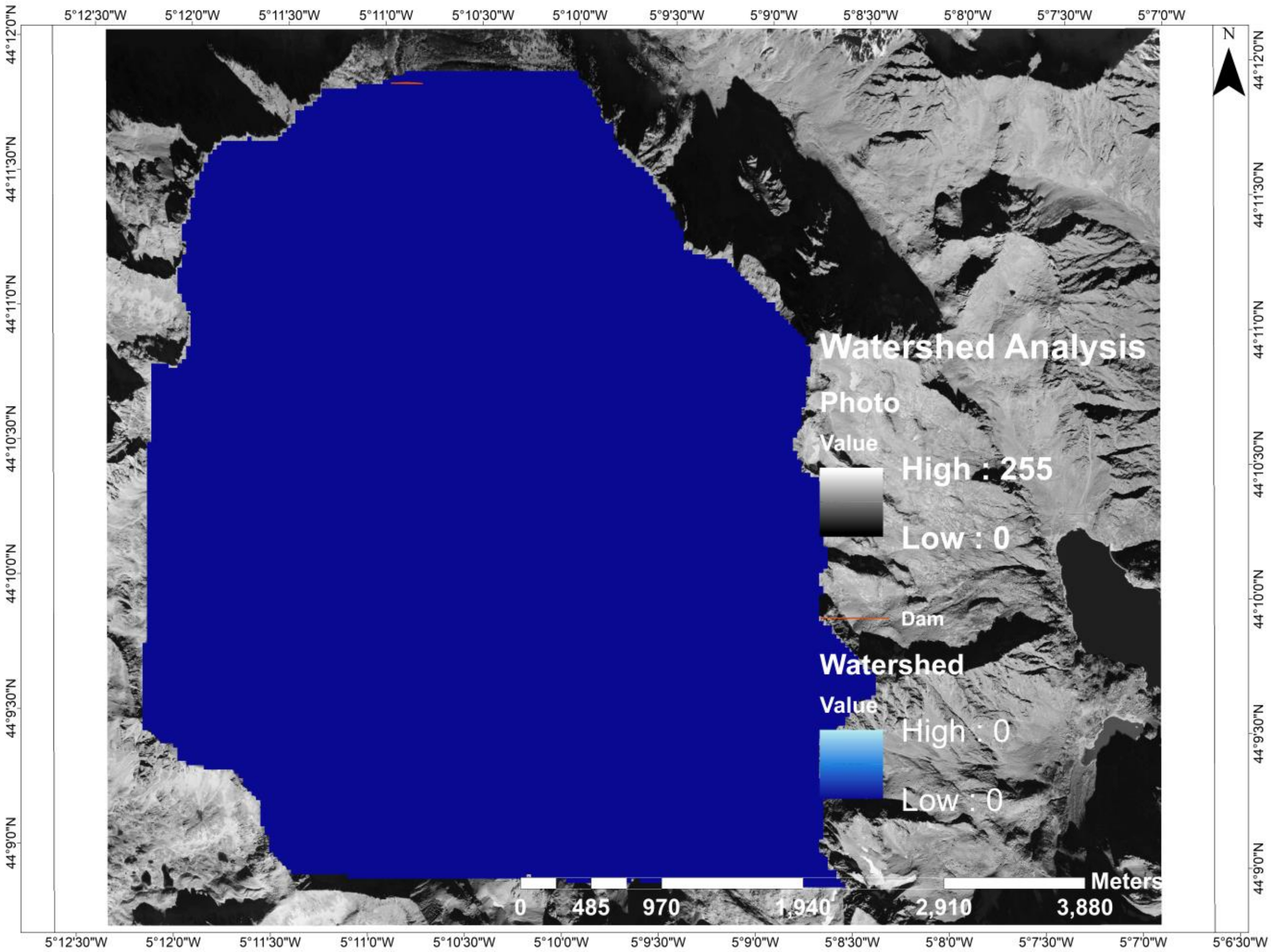


Fig. 16. Watershed analysis to find maximum water accumulation for dam and reservoir.

6: Digitise the extent of the reservoir.

As the location of the dam is identified and its height is determined to be at the elevation of 1500m above sea level, thus the water level is expected to remain at 1500m elevation assuming there is required amount of precipitation in the area. Hence, a polygon representing the reservoir is created with its boundaries aligning to the contour lines at 1500m elevation as shown in the fig. 17 and fig. 18. Also, Fig. 19 confirms the extent of the reservoir to be aligned with the TIN generated for the area.

Further, area and volume are calculated with the use of Polygon Volume tool from 3D Analyst Tools as shown in fig. 20 (Polygon Volume, 2021). The tool requires TIN in the Input Surface field, ‘Reservoir’ polygon in the Input Feature Class field. Height field must be present and populated in the attribute table of the polygon (in this case height field was set to 1500m), Reference Plane field to be selected as ‘BELOW’ for volume calculation to be considered below the polygon plane, and Volume and Area field names to be mentioned based on their respective column names in the attribute table. Then, area and volume of the reservoir gets calculated by the tool and populated in the respective columns in the attribute table of the 'Reservoir' polygon as shown in fig. 21.

Below is the calculated area and volume of the reservoir (Linear unit of the reservoir is Meter).

Area = 68,082.59 sq. meters.

Volume = 813,685.09 cubic meters.

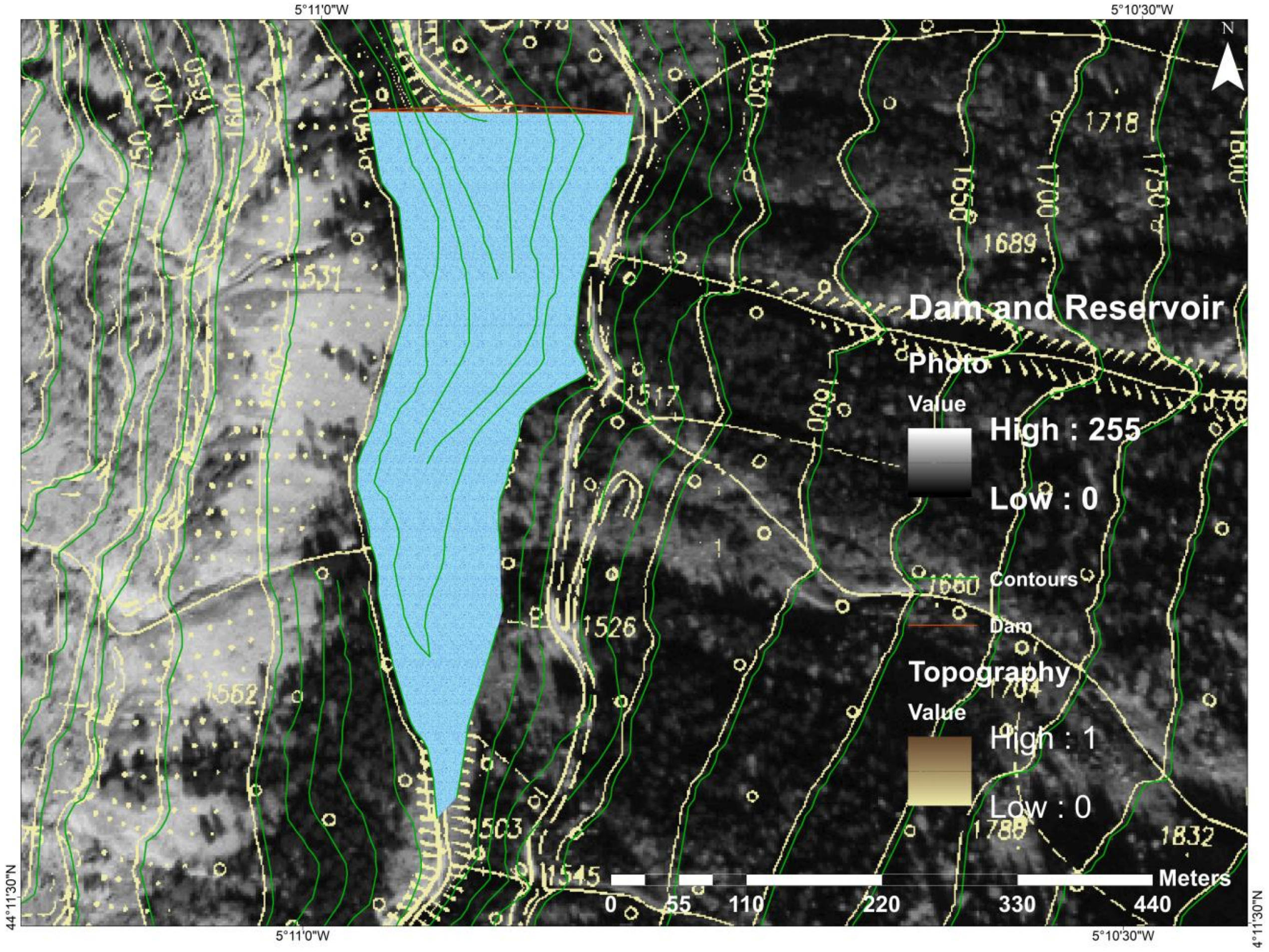


Fig. 17. Dam and Reservoir polygon with topography and contour line reference.

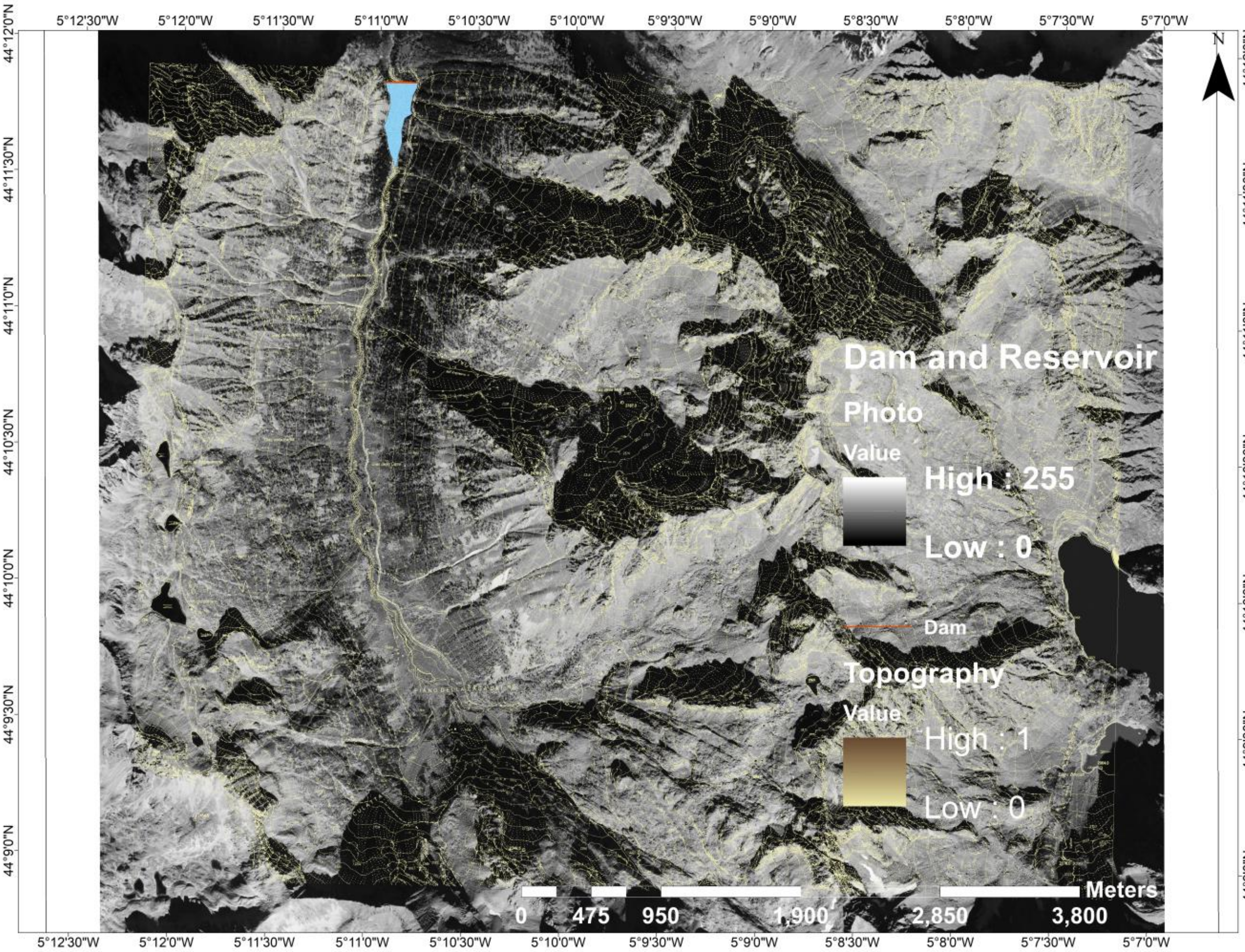


Fig. 18. Dam and Reservoir with topography (Full Extent).

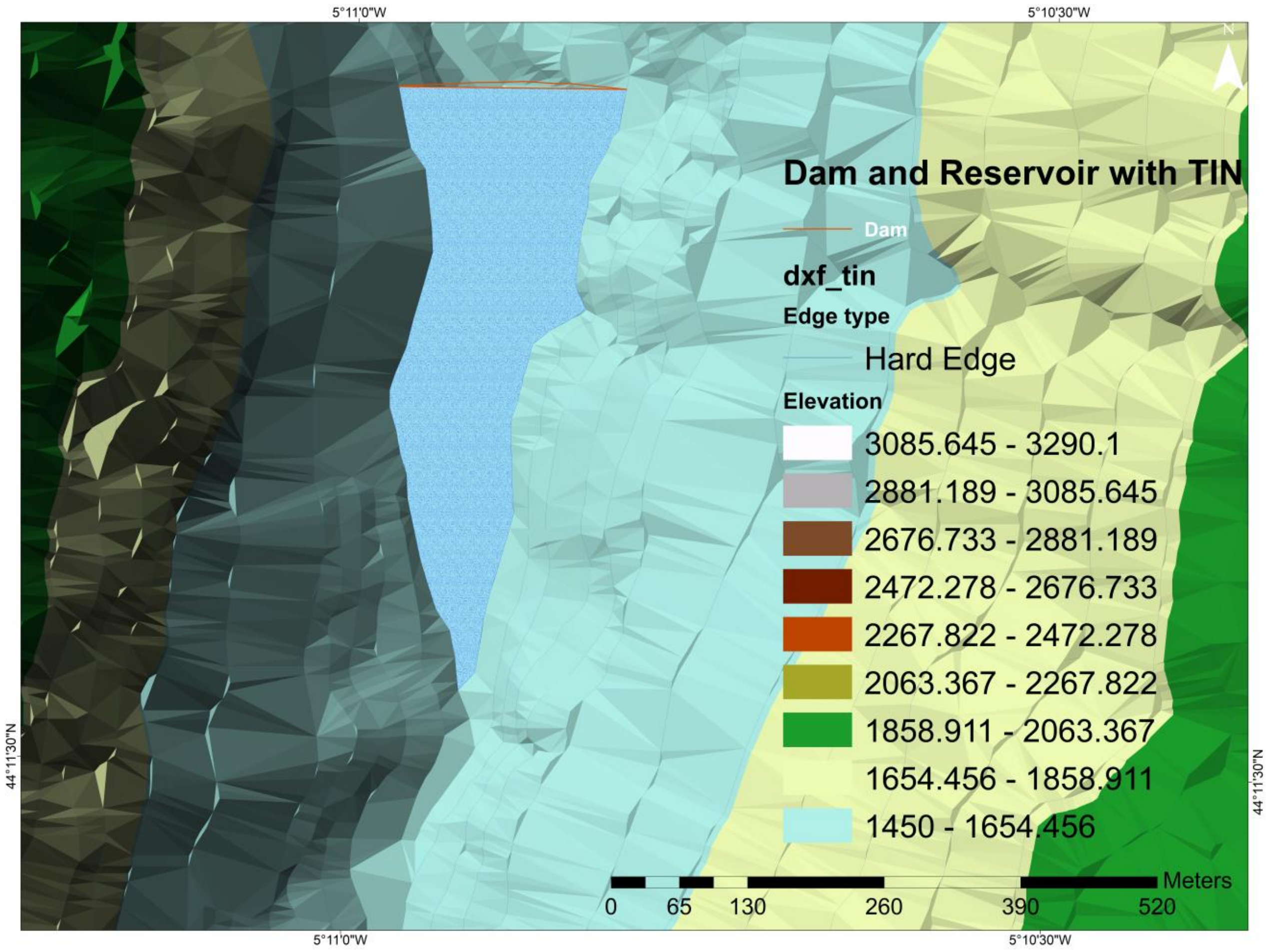


Fig. 19. Dam and Reservoir with reference to TIN.

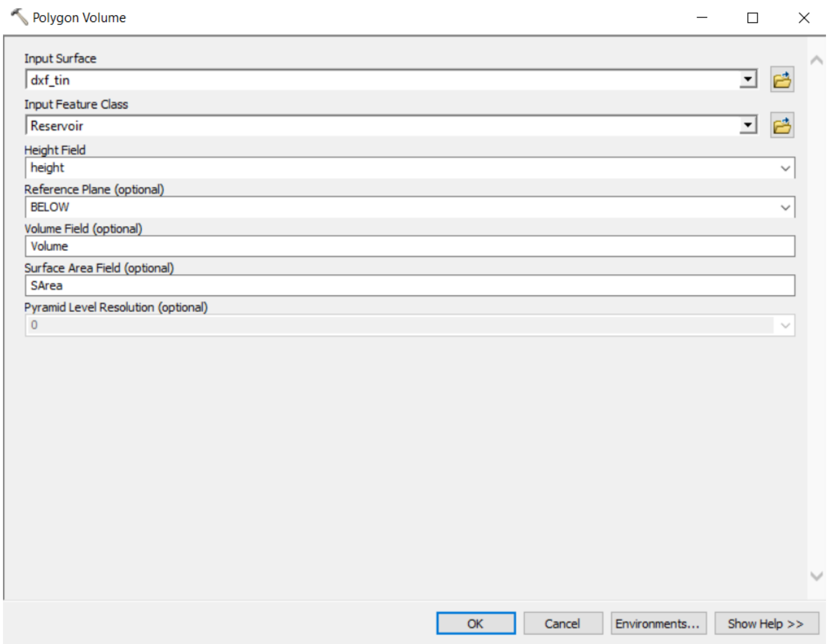
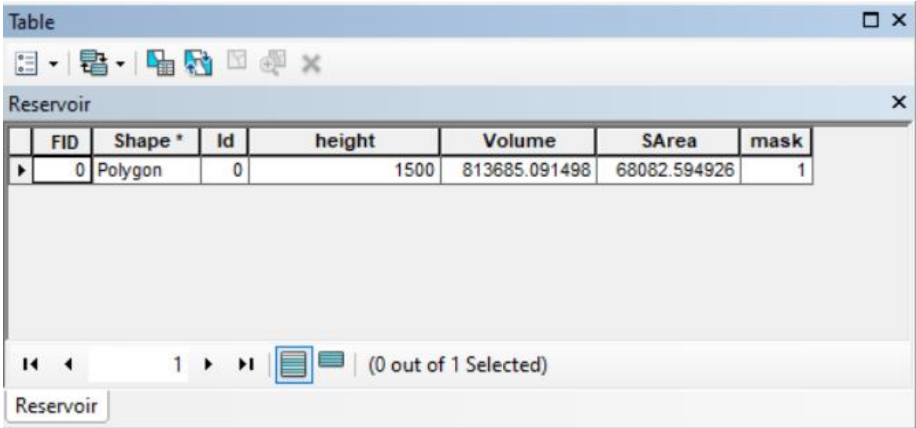


Fig. 20. Area and volume calculation using Polygon Volume (3D Analyst) tool.



FID	Shape *	Id	height	Volume	SArea	mask
0	Polygon	0	1500	813685.091498	68082.594926	1

Fig. 21. Area and Volume calculated and populated in the attribute table of Reservoir polygon.

7: Land cover area measurements.

To measure the land cover areas under the reservoir, first, the reservoir polygon is used to clip the geo-rectified photo raster using Clip (Data Management) tool as shown in fig. 22. Refer the clipped photo raster in fig. 23. The clipped reservoir photo is then used with Image Classification toolbar features as shown in fig. 24. Next, sample polygons were created for land cover units such as trees, grass and soil as shown in fig. 25. Further, Interactive Supervised Classification under Classification menu was run to map other similar land cover units within the clipped photo as shown in fig. 26a and fig. 26b. Subsequently, Raster to Polygon tool (Conversion Tools) was used to convert land cover classification raster to polygons so area can be calculated under each classified land cover unit as shown in fig. 27. Additionally, ‘Area’ field was added to the attribute table of the newly created polygon shape file as shown in fig. 28, and area of all the types of polygons is then calculated using ‘Calculate Geometry’ option by right clicking the ‘Area’ column as shown in fig. 29 and fig. 30.

The calculated area for each land cover units are mentioned below.

Area for Trees: 34,314.47 sq. meters.
Area for Grass: 26,358.46 sq. meters.
Area for Soil: 5,368.98 sq. meters.

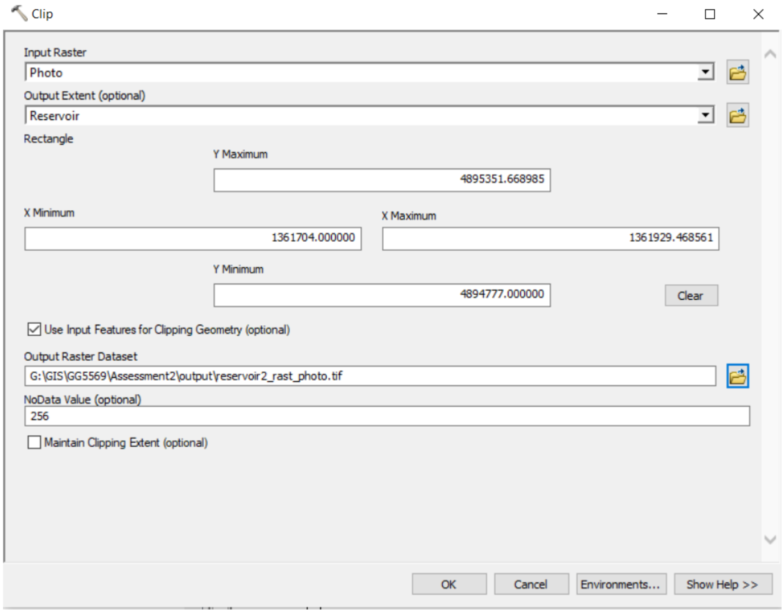


Fig. 22. Reservoir polygon used to clip area from the photo raster using Clip (Data Management) tool.

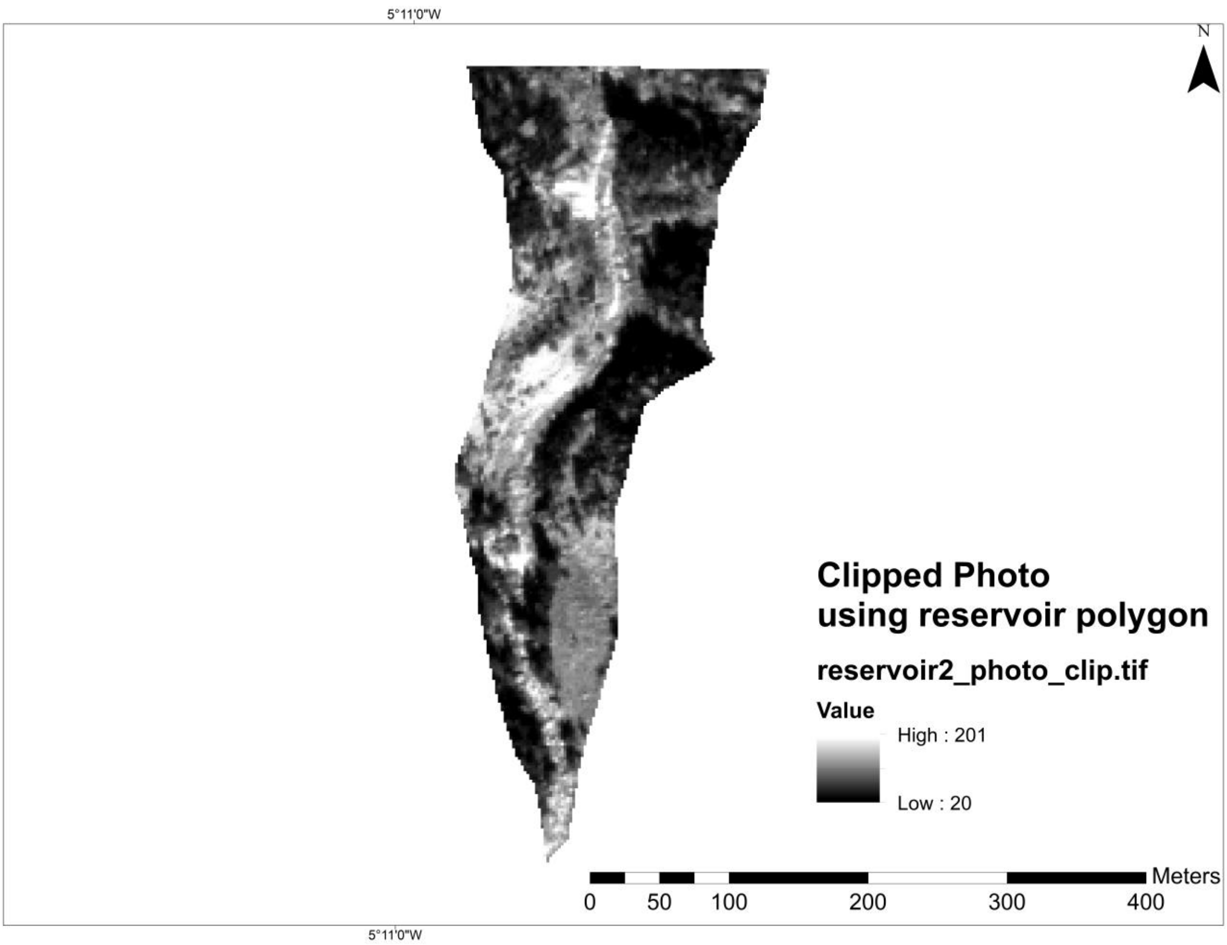


Fig. 23. Area extracted from photo using reservoir polygon.

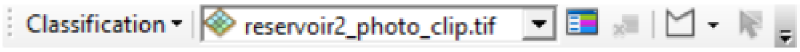
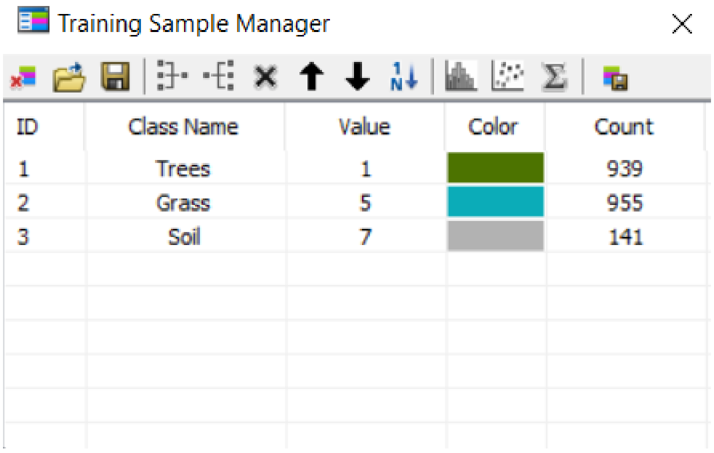


Fig. 24. Image Classification toolbar.



ID	Class Name	Value	Color	Count
1	Trees	1		939
2	Grass	5		955
3	Soil	7		141

Fig. 25. Training Samples created from reservoir photo clip.

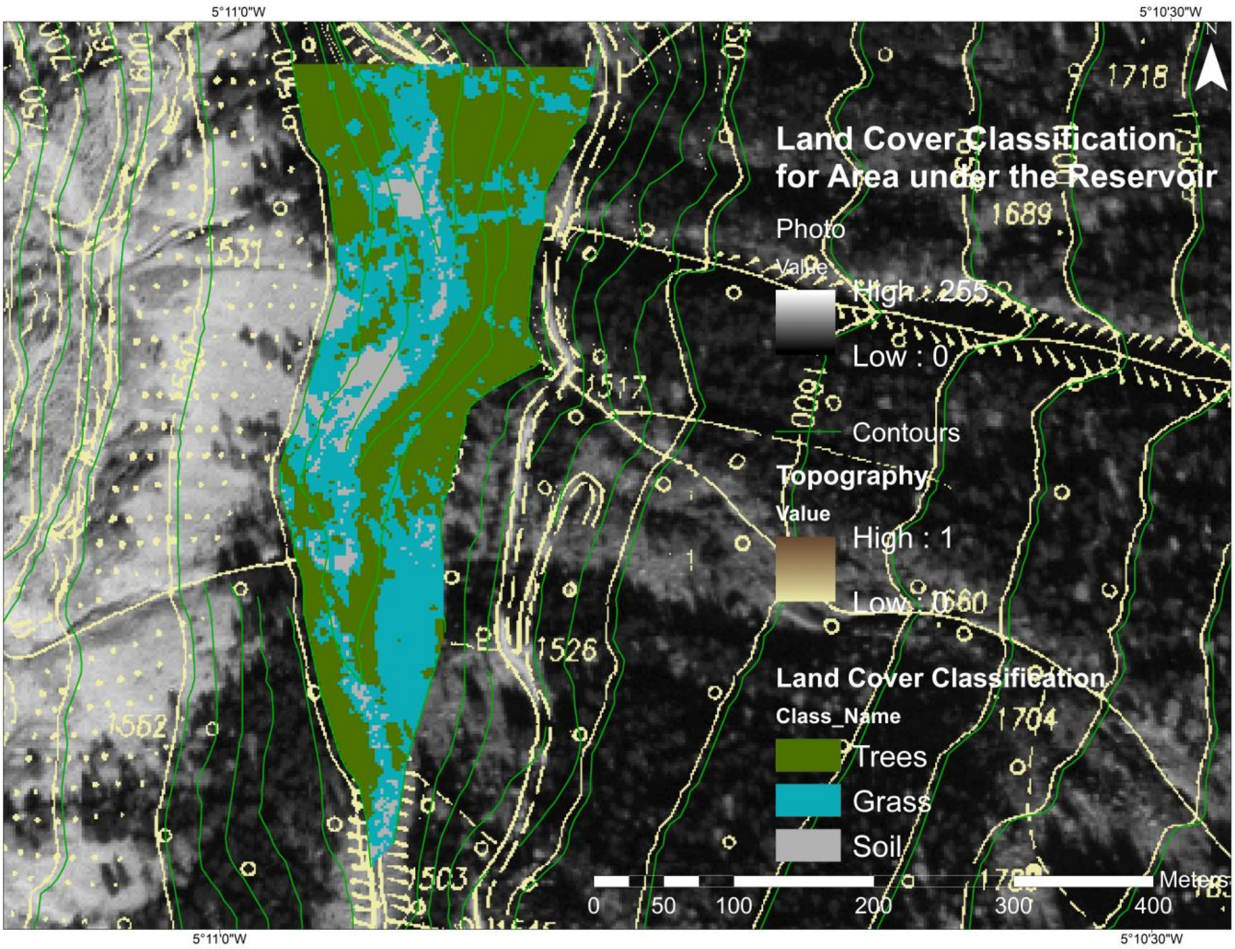


Fig. 26a. Land Cover Classification using Interactive Supervised Classification tool.

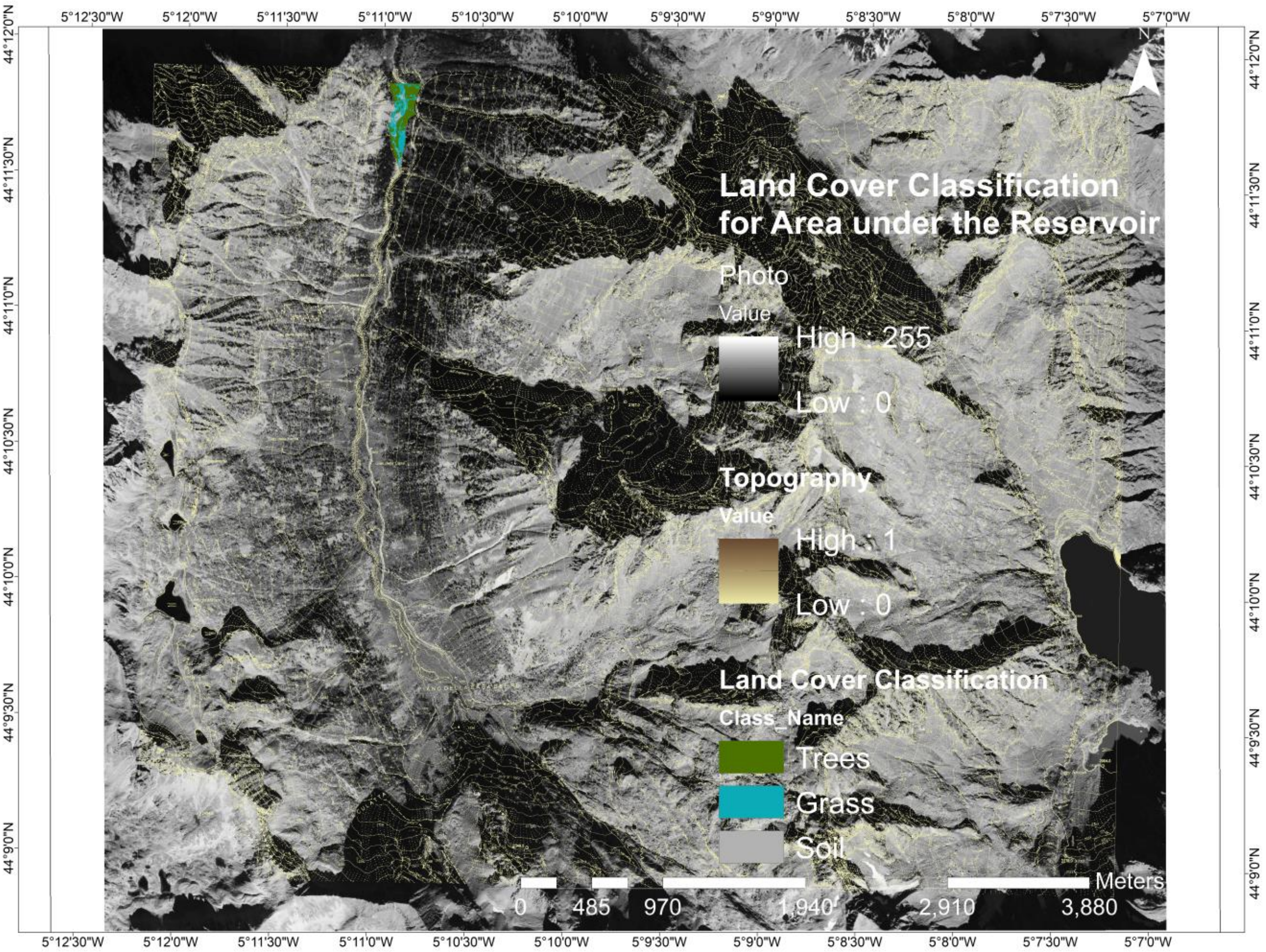


Fig. 26b. Land Cover Classification for area under the reservoir (Zoomed out).

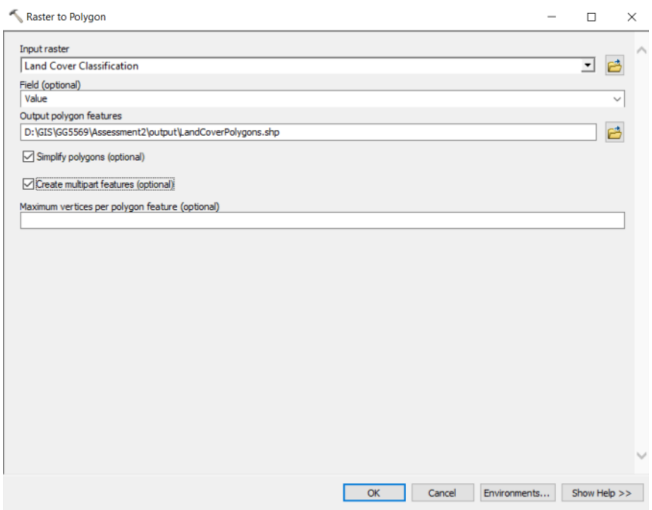


Fig. 27. Land Cover Classification Raster to Polygon shapefile.

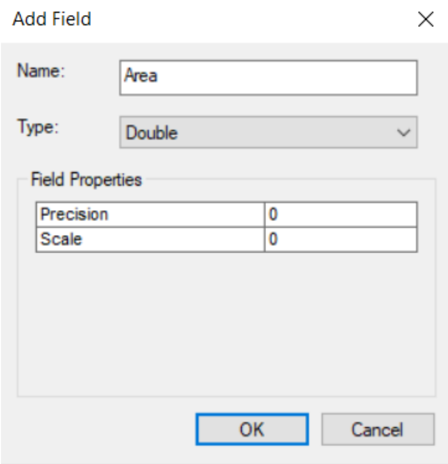
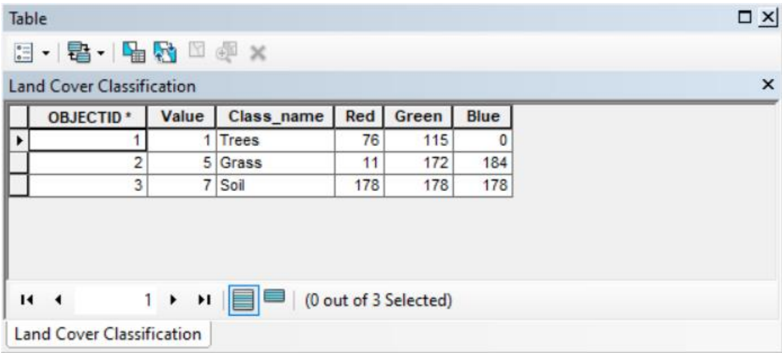
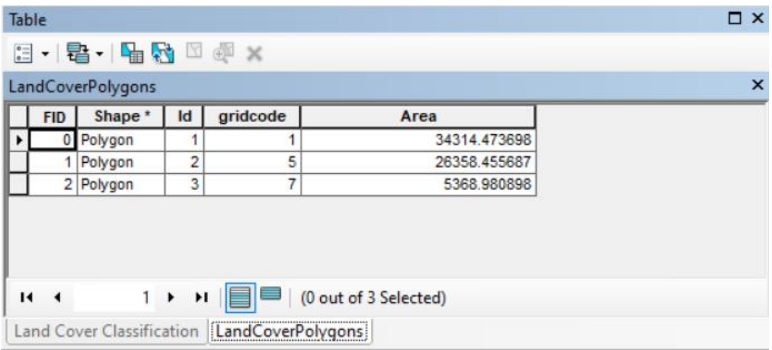


Fig. 28. Area field added to Land Cover Polygon shape file attribute table.



OBJECTID *	Value	Class_name	Red	Green	Blue
1	1	Trees	76	115	0
2	5	Grass	11	172	184
3	7	Soil	178	178	178

Fig. 29. The attribute table of Land Cover Classification Raster.



FID	Shape *	Id	gridcode	Area
0	Polygon	1	1	34314.473698
1	Polygon	2	5	26358.455687
2	Polygon	3	7	5368.980898

Fig. 30. The attribute table of Land Cover Classification polygon shapefile.

CONCLUSION

After careful analysis of the alpine region, it is determined that the region is covered with streams, roads, trees and lakes, and its elevation ranges between 1450m and 3278m. A lower elevation, accessibility to roads and water accumulation analysis proved conclusive for an ideal location for a dam and a reservoir as detailed in task 5 and 6 earlier. Although the best location for dam was identified, but the level of water in the reservoir will depend on amount of precipitation occurs in the region.

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APPENDICES