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Research Article

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Enhancing the Glacial Lake Inventory in Bhutan through Semi-Automatic Techniques using Google Earth Engine and QGIS for the Phochhu Basin

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Abstract

Bhutan located in the Hindu Kush Himalayan (HKH) region consists of several glaciers and glacial lakes at higher elevations. With the rapid change in global temperature, glaciers are found to melt at an accelerated rate. This rapid melt of glaciers gets accumulated in weak moraine walls forming a glacial lake, posing a major threat to the downstream communities. As per the Bhutan Glacial Lake Inventory 2021, Bhutan has 567 glacial lakes. Furthermore, the Phochhu basin has the maximum glacial lakes (0.05%) and of which 9 are PDGL. Hence a need for a time monitoring system is imminent. With the availability of free High-resolution Satellite Imageries and Advanced Remote Sensing tools, it has been a sine qua no for monitoring glacial lakes in high areas. Therefore, using the Google Earth Engine and Qgis Platform a semi-automated technique was used to generate glacial lake inventories for Phochhu Sub-basin for the year 2021. We found out that there are 166 glacial lakes covering an area of 24.051 km2.

Keywords: Glacial Lake Inventory (Rapstreng, Thorthomi, and Luggye), Sentinel-2 MSI, Normalized Difference Water Index, Semi-Automatic Delineation.

1. Introduction

When the surface temperatures in the high altitudes are rising due to climate change, the rising temperatures and higher precipitation potentially trigger glacial lakes to burst and cause catastrophic flood downstream [1]. In Bhutan 17 glacial lakes are identified as potentially dangerous lakes but Rapstreng Lake and Tortoni lakes remain an imminent threat to western Bhutan in Punakha along the Shochu River. Restring is a fully formed lake with an area of 1.31 km2. It is separated from the bigger Tortoni Lake by a narrow moraine wall, which is made up of ice and water blocks and stretches for an area of 3.62 km2. If the ice block in Tortoni melts with increasing pressure, it will cause the moraine wall to collapse, considered one of the most dan-gerous glacial lakes in Bhutan [2].

The tiny size of glacial lakes, cloud cover in optical satellite imageries, shadows from mountains and clouds, seasonal snow in satellite photos, varying degrees of turbidity among glacial lakes, and frozen glacial lake surfaces all make mapping of glacial lakes in the Shochu basin difficult. We used a cloud-based tool called "Google Earth Engine" to construct an automated method for mapping glacier lakes in the Shochu basin for this work.

2. Material and Methods

2.1. Objectives

The main aims of this report are to

- Study the spatial distribution of glacial lakes in Shochu basin using geospatial techniques.
- Helps in the development of glacial lake maps.
- To monitor potentially dangerous glacial lakes in Phochhu basin.

2.2. Study Area

The main emphasis of this Glacial Lake Inventory is the Phochhu Basin, which contains the majority of gla-cial lakes as well as potentially dangerous lakes such as Thorthomi Tsho, Rapstreng Tsho, and Luggye Tsho. The figure 1 shows the study area map of Phochhu basin.

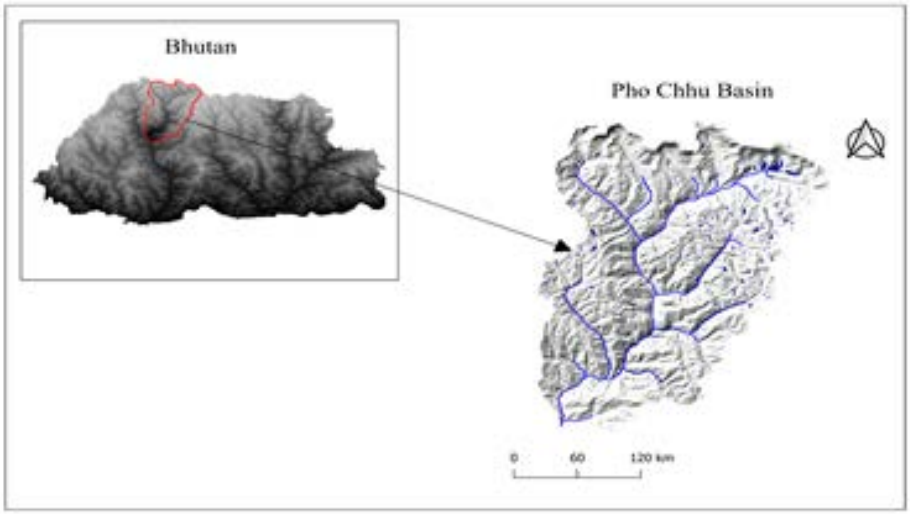

Figure 1. Study area map of Phochhu Basin

2.3. Data Resources

Because of their spatial resolution and accessibility, Landsat satellite images have been frequently utilized to track the extent of glaciers and glacial lakes around the world in the past. Sentinel 2 images have been used in this study due to their consistent spatial coverage with a high spatial resolution of 10m and temporal reso-lution which is free accessibility on cloud-based (Google Earth Engine) and web portals (https://scihub.copernicus.eu/). We have used the Sentinel 2 MSI to prepare the glacial lake inventory of the Phochhu basin for 2021. Images taken between September and December were used primarily because there is a lesser likelihood of snow or cloud cover during this period compared to other months of the year.

For this study, SRTM DEM 30m resolution was used for the extraction of Phochhu Basin. The Advanced Land Observing Satellite (ALOS) DEMs of a 10m resolution was used to carry out terrain analysis in order to correct shadows as misclassified lakes.

2.4. Methodology

The SRTM 30m DEM was used to extract the Phochhu basin. The Phochhu basin was used in the Google Earth Engine for sentinel-2 imageries with false color composite. Then NDWI was also calculated for auto-matic delineation of Glacial Lake and converted NDWI raster into NDWI vector format (shp). The vector-ized NDWI mask was then exported to Google Drive and downloaded. Later it was imported to QGIS for further analysis. An area threshold of 0.01km was utilized for this inventory, misclassified lakes were man-ually removed using slope map generated from the ALOS DEM classifying. A slope threshold of 10 degrees was the glacial lake and glacial lake detected on slope degree more than 10 is removed because the lake sur-face of the area has to be plain. The delineation of the glacial lake using sentinel-2 imageries can be carried out using automatic and semi-automatic techniques. The glacial lake which is not detected by NDWI was manually delineated. The semi-automatic techniques can solve the problems faced in automatic techniques. Therefore, in this current preparation of the Glacial Lake Inventory of Phochhu basin the semi-automatic techniques were used which is shown below;

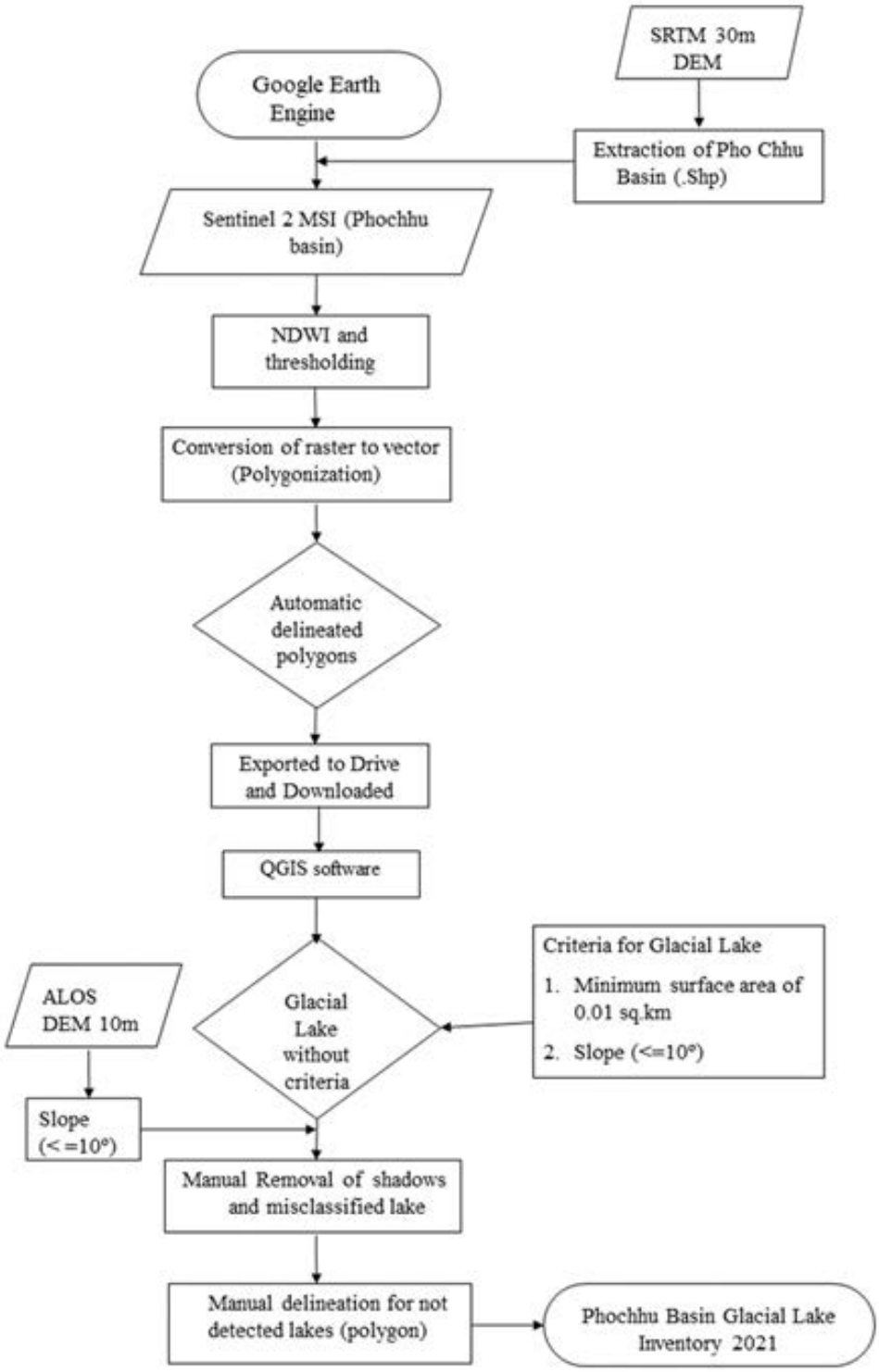

Figure 2: Workflow for semi-automatic delineation of the glacial lake of Phochhu basin using Sentinel-2 MSI

3. Results

The formation of glacial lakes is a continuous and dynamic process that requires constant monitoring and updating of glacial lake data. During the preparation of this inventory, 4463 water bodies (lakes) were dis-covered. Following the use of a separate set of criteria to designate a glacier lake, in total we found out that there are 166 glacial lakes in the Phochhu basin meet the criteria covering an area of 24.051 km2 accounting for 0.06 percent of the total area. The table 1 shows the area of glacial lakes.

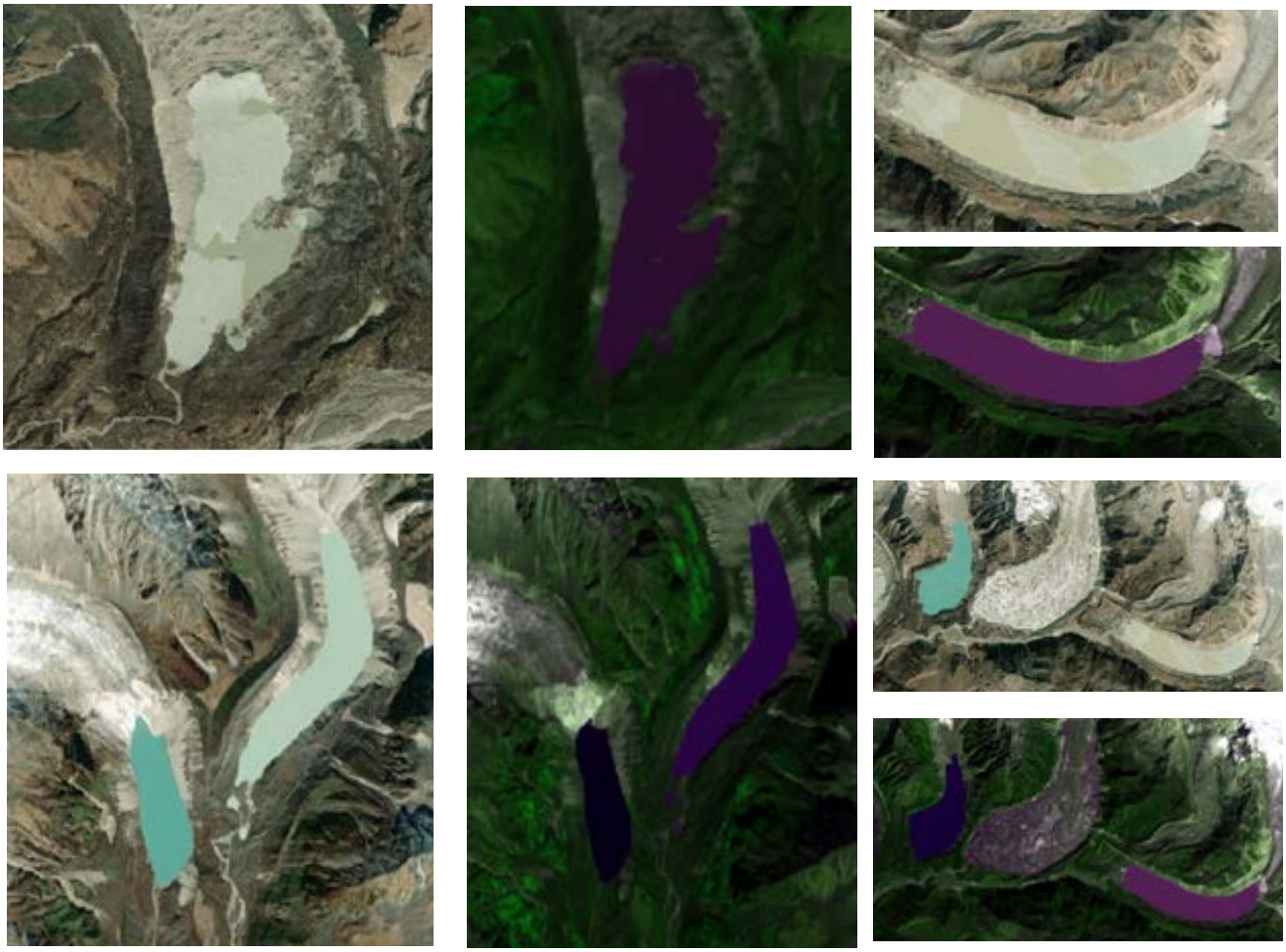

Figure 3: Glacial lake classification using NDWI on sentinel-2 with false color composite

Sl.no	Types of area calculated	Total Features	Area (Sq.km)	Area (%)
1	Area with all features	4463 features	18.843	0.05
2	Area with shadows (after Criteria)	233 features	16.344	0.04
3	Area without/removal of shadows	131 features	12.574	0.03
4	The final glacial lake area	166 features	24.051	0.06

Table 1. Glacial lake area

The threshold criteria for glacial lake identification using NDWI is kept at 0.2 since it detects most of the glacial lake perfectly. The ALOS DEM of 10m resolution was used to delete misclassified lakes. The lakes located on slope above 10° indicate hills and steep slopes are removed [3]. The automatic delineation of the lakes did provide glacial lake boundary for larger glaciers; however it also generated many misclassified lakes polygons as shown in figure 4. The manual delineation is done for misclassified lakes and undetected lakes to have accurate lake polygons. Interestingly while doing automatic delineation of the glacial lake few portions of lakes are detected since the surface of the lake is mostly covered with glaciers. In total, we found that there are 166 glacial lakes located in Phochhu basin covering an area of 24.051 km2 accounting for 0.06 percent of the total area of the Bhutan.

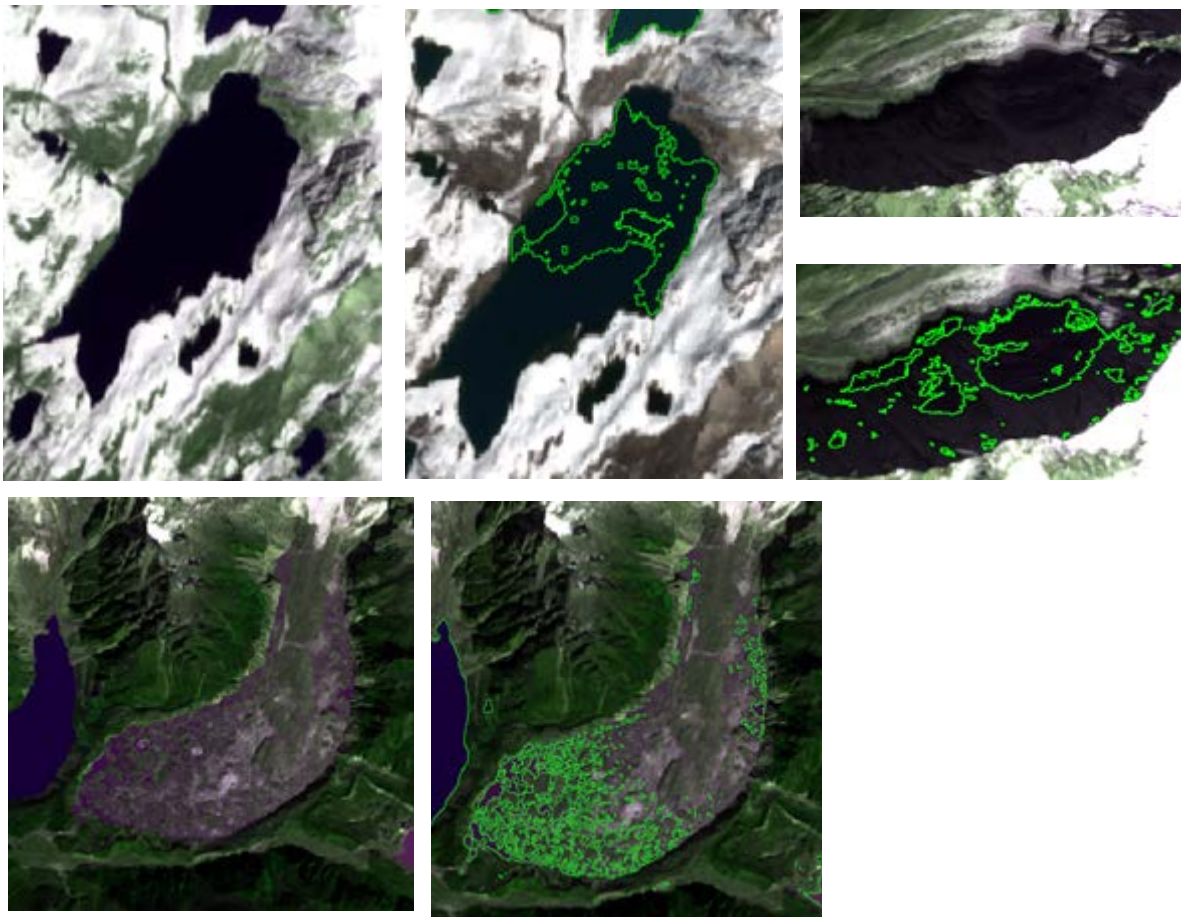

Figure 4: a). Misclassified glacial lake & 4b) Misclassified shadow as glacial lake using NDWI on senti-nel-2 with false color composite.

Among 166 glacial lakes in Phochhu basin Thorthomi glacial lake has highest area coverage. It has an area of 3.62 km2 followed by Luggye and Rapstreng covering an area 1.53 and 1.31 sq.km respectively. Figure 5 depicts the general distribution of glacial lakes in Phochhu basin

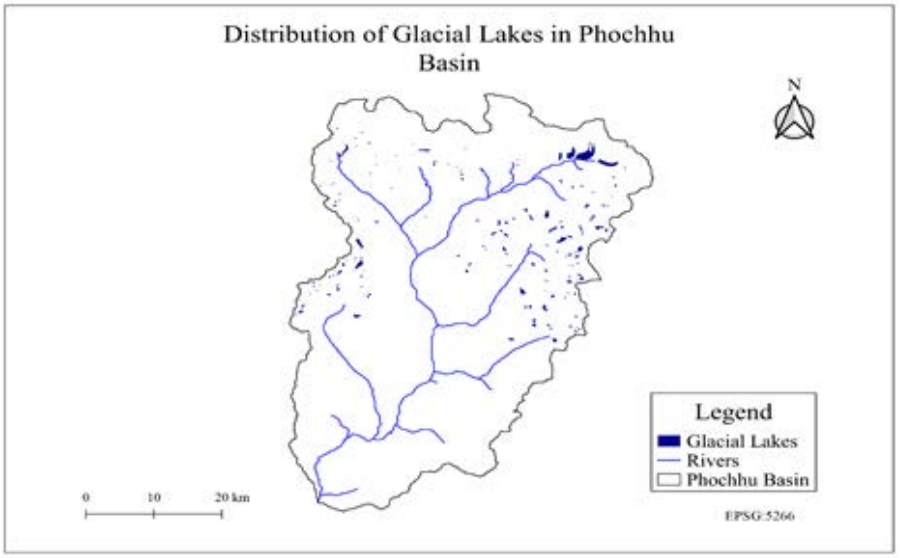

Figure 5: Distribution of glacial lakes in Phochhu basin

3.1. Hypsography

The hypsometric shows a clear picture of glacial lake distribution patterns in different elevations. The glacial lake in Phochhu basin has located a range between 4130 m.a.s.l to 5330 m.a.s.l shown in figure 6. Most of the glacial lakes are located in higher elevations since most of the glacial lakes are fed by glaciers. The max-imum number of the glacial lake is located at the elevation of 5030 m.a.s.l.

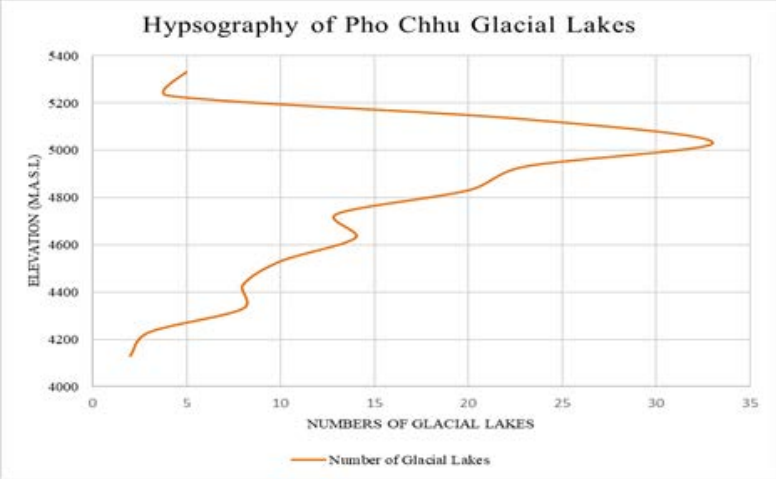

Figure 6: Hypsometry of Phochhu glacial lake distributions

3.2. Discussions

The method for Glacial Lake Inventory was built upon the existing studies and knowledge gained through a decade of research. The most used technique is manual editing of lakes after NDWI masking. The semi-automated techniques for the removal of misclassified lakes are used. The most widely used data for glacial lake mapping were Landsat data. The Bhutan glacial lake inventory was initially published by ICI-MOD in 2001 using Landsat data and also published a research article on Bhutan Glacial lake inventory by Wangchuk & Bolch (2020), using Sentinel 1 and 2 data [2]. The National Centre for Hydrology and Meteor-ology published a Bhutan Glacial lake inventory 2021 using Sentinel 1 and 2 data [4]. Different inventories published by different author/organization has kept different threshold for lake identification (e.g., ICIMOD inventories 2021 for Nepal is -0.6 to -0.9 for Landsat data and NCHM Bhutan Glacial Lake Inventories 2021 for Bhutan is less than 0.3 for Sentinel 2 MSI imageries [4]. Similarly, the criteria for the area are dif-ferent since ICIMOD (2021) kept the area above 0.003 km2 and NCHM (2021) kept the area above 0.01 km 2.

3.3. Comparison with Earlier Inventory

In 2001 ICIMOD prepared a glacial lake inventory for Bhutan and recorded 549 glacial lakes in Phochhu basin and 157 glacial lakes in 2021 inventory published by NCHM. However, the present inventory of the Phochhu basin has 166 glacial lakes which are 9 more than the NCHM inventory. For our study, the non-glaciers fed lakes are considered. That will be the reason for the increasing glacial lake at Phochhu basin. The table 2 shows the comparison among different inventories [6].

	ICIMOD 2001 (For Phochhu basin)	BGLI 2021 (For Phochhu basin)	PGLI 2021 (Phochhu Basin)
Number	549	157	166
Area (km^2)	23.49	20.98	24.051

Table 2: Comparison of number and changes in glacial lakes.

4. Conclusions

In conclusion to the glacial lake inventory of the Phochhu basin, it has the most potentially dangerous lake as compared to other basins in Bhutan namely Rapstreng, Thorthomi, and Luggye Lake. Phochhu basin has 166 glacial lakes in Phochhu basin covering an area of 24.051 sq.km accounting for 0.06%. Most of the studies reveal that the glaciers are retreating at an alarming rate with the rising temperature due to climate change. If preventive measures are not carried out, then there will be a high chance of glacial lake outburst flood in the downstream causing huge damage to life and properties. The glacial lakes are dynamic in nature therefore; glacial lake inventory has to update from time to time.

Author Contributions

Conceptualization, R.N.; methodology, R.N.; software, R.N.; validation, C.S.; and C.S.; formal analysis, R.N., C.S., and C.S.; investigation, R.N., and C.S.; resources, R.N., C.S., and C.S.; data curation, R.N.; writing—original draft preparation, R.N.; writing—review and editing, C.S; and C.S.; visualization, R.N.; supervision, R.N.; project administration, R.N. All authors have read and agreed to the published version of the manuscript

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Data Availability Statement: The data presented in this study are available on request from the correspond-ing author.

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Sentinel-2 and SRTM DEM are publicly, and thanks to the European Space Agency (ESA) and the Consul-tative Group on International Agricultural Research-Consortium for Spatial Information (CGIAR-CSI).
Lastly, I would like to acknowledge my intern mates and other friends for rendering support while doing my report.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix A

Phochhu Glacial Lake Inventory
Total number of Glacial lakes: 166 Total area: 24.051 km2

Object_ID	PGLI_ID	GLIMS_ID	Basin	Latitude	Longitude	Area (Km_2)	Elevation (m.a.s.l)	Local_ Name	Image _Year
1	Pho_gl 70	G090084E28069N	Phochhu	28.06936	90.08410	0.090	4660.7330		2021
2	Pho_gl 69	G090083E28077N	Phochhu	28.07661	90.08325	0.070	4711.2170		2021
3	Pho_gl 68	G090082E28082N	Phochhu	28.08186	90.08153	0.036	4706.6381		2021
4	Pho_gl 62	G090043E28096N	Phochhu	28.09584	90.04284	0.064	5104.8016		2021
5	Pho_gl 61	G090042E28092N	Phochhu	28.09165	90.04164	0.089	5039.0335		2021
6	Pho_gl 66	G090063E28092N	Phochhu	28.09189	90.06346	0.023	4903.2414		2021
7	Pho_gl 67	G090075E28088N	Phochhu	28.08846	90.07520	0.023	4764.9234		2021
8	Pho_gl 17	G089886E27923N	Phochhu	27.92267	89.88593	0.063	4841.1497		2021
9	Pho_gl 18	G089891E27925N	Phochhu	27.92526	89.89148	0.032	4874.4438		2021
10	Pho_gl 21	G089883E27931N	Phochhu	27.93065	89.88337	0.018	4935.2167		2021
11	Pho_gl 19	G089900E27929N	Phochhu	27.92933	89.90026	0.227	4945.0899		2021
12	Pho_gl 24	G089906E27941N	Phochhu	27.94106	89.90605	0.135	5029.0532		2021
13	Pho_gl 27	G089923E27948N	Phochhu	27.94826	89.92341	0.018	5071.5389		2021
14	Pho_gl 26	G089910E27948N	Phochhu	27.94785	89.91006	0.017	5079.7225		2021
15	Pho_gl 12	G089898E27904N	Phochhu	27.90401	89.89812	0.118	4784.0404		2021
16	Pho_gl 8	G089885E27896N	Phochhu	27.89601	89.88461	0.112	4563.9039		2021
17	Pho_gl 14	G089897E27909N	Phochhu	27.90939	89.89733	0.061	4868.7374		2021
18	Pho_gl 16	G089861E27915N	Phochhu	27.91480	89.86114	0.078	4742.5543		2021
19	Pho_gl 5	G089846E27880N	Phochhu	27.87968	89.84642	0.073	4584.6740		2021
20	Pho_gl 4	G089845E27877N	Phochhu	27.87722	89.84464	0.061	4587.1431		2021
21	Pho_gl 3	G089843E27870N	Phochhu	27.87034	89.84255	0.214	4505.5084		2021
22	Pho_gl 2	G089835E27866N	Phochhu	27.86554	89.83464	0.041	4555.4504		2021
23	Pho_gl 7	G089856E27897N	Phochhu	27.89731	89.85630	0.025	4574.9224		2021
24	Pho_gl 11	G089866E27903N	Phochhu	27.90256	89.86648	0.028	4573.3249		2021
25	Pho_gl 13	G089862E27909N	Phochhu	27.90861	89.86173	0.046	4687.1247		2021
26	Pho_gl 15	G089872E27910N	Phochhu	27.90972	89.87166	0.017	4741.1617		2021

27	Pho_gl 10	G089946E27897N	Phochhu	27.89654	89.94557	0.079	4860.8232		2021
28	Pho_gl 9	G089943E27893N	Phochhu	27.89290	89.94280	0.085	4845.9766		2021
29	Pho_gl 22	G089922E27933N	Phochhu	27.93331	89.92209	0.020	4978.0503		2021
30	Pho_gl 44	G089887E28097N	Phochhu	28.09692	89.88690	0.030	4739.2259		2021
31	Pho_gl 51	G089934E28139N	Phochhu	28.13936	89.93370	0.035	5069.8736		2021
32	Pho_gl 97	G090310E28072N	Phochhu	28.07196	90.31040	0.055	5042.1324		2021
33	Pho_gl 91	G090232E28066N	Phochhu	28.06621	90.23161	0.115	4728.6070		2021
34	Pho_gl 102	G090249E28057N	Phochhu	28.05733	90.24939	0.081	5128.3918		2021
35	Pho_gl 115	G090234E27997N	Phochhu	27.99727	90.23355	0.112	4978.4924		2021
36	Pho_gl 129	G090222E27995N	Phochhu	27.99545	90.22206	0.213	4934.2824		2021
37	Pho_gl 130	G090216E27992N	Phochhu	27.99203	90.21579	0.173	4934.4375		2021
38	Pho_gl 90	G090211E28016N	Phochhu	28.01611	90.21059	0.546	5128.7748	Tsho Chena	2021
39	Pho_gl 89	G090187E28012N	Phochhu	28.01163	90.18683	0.208	5141.4725		2021
40	Pho_gl 88	G090179E28023N	Phochhu	28.02280	90.17934	0.162	5074.1911		2021
41	Pho_gl 80	G090147E27964N	Phochhu	27.96425	90.14673	0.219	4880.4836		2021
42	Pho_gl 150	G090174E27901N	Phochhu	27.90053	90.17374	0.487	4674.6552		2021
43	Pho_gl 149	G090219E27893N	Phochhu	27.89336	90.21891	0.162	4973.8740		2021
44	Pho_gl 159	G090157E27829N	Phochhu	27.82900	90.15708	0.234	4429.4764		2021
45	Pho_gl 155	G090191E27850N	Phochhu	27.85041	90.19132	0.232	4763.6804		2021
46	Pho_gl 158	G090222E27827N	Phochhu	27.82736	90.22180	0.293	4658.7205		2021
47	Pho_gl 154	G090191E27857N	Phochhu	27.85700	90.19133	0.160	4722.0031		2021
48	Pho_gl 152	G090185E27878N	Phochhu	27.87765	90.18535	0.146	4824.0541		2021
49	Pho_gl 151	G090179E27877N	Phochhu	27.87736	90.17858	0.094	4838.5798		2021
50	Pho_gl 145	G090254E27863N	Phochhu	27.86275	90.25391	0.071	4946.2053		2021
51	Pho_gl 157	G090216E27845N	Phochhu	27.84508	90.21596	0.065	4799.7703		2021
52	Pho_gl 156	G090213E27850N	Phochhu	27.84990	90.21267	0.095	4852.7941		2021
53	Pho_gl 164	G090190E27942N	Phochhu	27.94156	90.18973	0.163	4622.3388		2021
54	Pho_gl 146	G090209E27932N	Phochhu	27.93186	90.20925	0.116	4985.8593		2021
55	Pho_gl 140	G090226E27961N	Phochhu	27.96071	90.22613	0.051	5047.0098		2021
56	Pho_gl 78	G090139E28002N	Phochhu	28.00242	90.13903	0.151	5056.8298		2021
57	Pho_gl 76	G090131E27988N	Phochhu	27.98782	90.13056	0.195	5032.7758		2021
58	Pho_gl 83	G090149E27986N	Phochhu	27.98554	90.14934	0.165	4903.7797		2021
59	Pho_gl 79	G090142E27992N	Phochhu	27.99163	90.14224	0.092	4970.9389		2021
60	Pho_gl 77	G090139E28007N	Phochhu	28.00666	90.13917	0.088	5047.9245		2021
61	Pho_gl 84	G090150E28004N	Phochhu	28.00401	90.15006	0.135	5000.7430		2021
62	Pho_gl 32	G089928E28008N	Phochhu	28.00806	89.92816	0.033	5030.6798		2021
63	Pho_gl 33	G089893E28030N	Phochhu	28.02963	89.89327	0.104	5029.1856		2021
64	Pho_gl 34	G089895E28036N	Phochhu	28.03561	89.89454	0.055	5188.2178		2021
65	Pho_gl 35	G089901E28038N	Phochhu	28.03776	89.90051	0.037	5208.0676		2021
66	Pho_gl 43	G089871E28059N	Phochhu	28.05943	89.87113	0.035	5117.5788		2021
67	Pho_gl 37	G089900E28047N	Phochhu	28.04705	89.90027	0.045	5007.4079		2021
68	Pho_gl 38	G089889E28061N	Phochhu	28.06076	89.88922	0.026	4895.5057		2021
69	Pho_gl 39	G089892E28064N	Phochhu	28.06436	89.89228	0.027	4854.1798		2021
70	Pho_gl 81	G090150E27957N	Phochhu	27.95679	90.15011	0.055	4818.6933		2021
71	Pho_gl 82	G090155E27939N	Phochhu	27.93929	90.15491	0.077	4504.9961		2021
72	Pho_gl 36	G090029E28013N	Phochhu	28.01287	90.02947	0.037	4417.0276		2021
73	Pho_gl 63	G090078E27954N	Phochhu	27.95445	90.07845	0.084	4769.3636		2021
74	Pho_gl 64	G090091E27931N	Phochhu	27.93112	90.09062	0.145	4515.7660		2021
75	Pho_gl 65	G090095E27942N	Phochhu	27.94158	90.09522	0.096	4633.6293		2021

76	Pho_gl 31	G089956E28005N	Phochhu	28.00531	89.95574	0.117	4606.2117		2021
77	Pho_gl 6	G089840E27888N	Phochhu	27.88762	89.84028	0.032	4656.9502		2021
78	Pho_gl 114	G090231E28005N	Phochhu	28.00547	90.23145	0.049	5067.9616		2021
79	Pho_gl 87	G090161E28010N	Phochhu	28.01001	90.16127	0.078	5044.1990		2021
80	Pho_gl 1	G089926E27864N	Phochhu	27.86385	89.92625	0.351	4522.7971		2021
81	Pho_gl 116	G089933E27908N	Phochhu	27.90785	89.93339	0.037	4839.1771		2021
82	Pho_gl 94	G090270E28106N	Phochhu	28.10628	90.26953	3.615	4450.1922	Thorthomi	2021
83	Pho_gl 52	G089896E28146N	Phochhu	28.14567	89.89644	0.037	5107.0987		2021
84	Pho_gl 45	G089899E28106N	Phochhu	28.10593	89.89863	0.236	4265.4842		2021
85	Pho_gl 46	G089909E28114N	Phochhu	28.11396	89.90935	0.449	4338.2057		2021
86	Pho_gl 165	G089925E27951N	Phochhu	27.95123	89.92478	0.039	5063.2564		2021
87	Pho_gl 50	G089924E28131N	Phochhu	28.13063	89.92431	0.032	5065.6486		2021
88	Pho_gl 30	G089930E27973N	Phochhu	27.97336	89.93019	0.628	5071.8259		2021
89	Pho_gl 48	G089925E28119N	Phochhu	28.11899	89.92485	0.030	4612.7993		2021
90	Pho_gl 25	G089930E27941N	Phochhu	27.94117	89.92996	0.705	4996.6530		2021
91	Pho_gl 29	G089931E27965N	Phochhu	27.96455	89.93136	0.022	5125.7897		2021
92	Pho_gl 20	G089933E27924N	Phochhu	27.92368	89.93307	0.064	4824.0174		2021
93	Pho_gl 28	G089933E27950N	Phochhu	27.95009	89.93305	0.063	5035.0823		2021
94	Pho_gl 23	G089936E27932N	Phochhu	27.93189	89.93619	0.018	4922.5932		2021
95	Pho_gl 49	G089945E28124N	Phochhu	28.12398	89.94491	0.057	4747.0541		2021
96	Pho_gl 40	G089946E28078N	Phochhu	28.07848	89.94623	0.033	4697.1487		2021
97	Pho_gl 42	G089956E28091N	Phochhu	28.09080	89.95550	0.021	4925.1274		2021
98	Pho_gl 53	G089985E28104N	Phochhu	28.10441	89.98488	0.027	5020.7684		2021
99	Pho_gl 41	G089990E28085N	Phochhu	28.08485	89.98979	0.019	5005.4663		2021
100	Pho_gl 55	G090012E28108N	Phochhu	28.10753	90.01158	0.017	4577.3046		2021
101	Pho_gl 58	G090030E28060N	Phochhu	28.06045	90.02952	0.061	4380.6264		2021
102	Pho_gl 57	G090030E28070N	Phochhu	28.07012	90.02979	0.027	4389.5129		2021
103	Pho_gl 59	G090035E28057N	Phochhu	28.05714	90.03528	0.051	4366.5529		2021
104	Pho_gl 60	G090035E28042N	Phochhu	28.04226	90.03458	0.025	4328.8780		2021
105	Pho_gl 56	G090028E28113N	Phochhu	28.11293	90.02765	0.373	4684.1453		2021
106	Pho_gl 72	G090106E28007N	Phochhu	28.00738	90.10642	0.085	4529.2313		2021
107	Pho_gl 73	G090113E28084N	Phochhu	28.08445	90.11311	0.081	4132.4213		2021
108	Pho_gl 74	G090115E27969N	Phochhu	27.96874	90.11520	0.063	4986.5692		2021
109	Pho_gl 75	G090119E27964N	Phochhu	27.96372	90.11919	0.031	4872.5197		2021
110	Pho_gl 86	G090167E28090N	Phochhu	28.09050	90.16700	0.046	4212.6409		2021
111	Pho_gl 85	G090167E28098N	Phochhu	28.09825	90.16687	0.024	4259.4520		2021
112	Pho_gl 147	G090209E27917N	Phochhu	27.91700	90.20934	0.070	4895.4657		2021
113	Pho_gl 153	G090207E27876N	Phochhu	27.87590	90.20712	0.395	4908.4793		2021
114	Pho_gl 148	G090207E27902N	Phochhu	27.90230	90.20723	0.018	4948.8182		2021
115	Pho_gl 166	G090211E27970N	Phochhu	27.97011	90.21055	0.058	4894.8130		2021
116	Pho_gl 131	G090233E27978N	Phochhu	27.97804	90.23284	0.684	5071.3220		2021
117	Pho_gl 132	G090240E27953N	Phochhu	27.95308	90.23970	0.035	5126.1570		2021
118	Pho_gl 139	G090244E27915N	Phochhu	27.91534	90.24391	0.227	5152.1527		2021
119	Pho_gl 133	G090244E27940N	Phochhu	27.94049	90.24409	0.019	5101.2487		2021
120	Pho_gl 126	G090245E27954N	Phochhu	27.95394	90.24546	0.027	5143.0296		2021
121	Pho_gl 138	G090244E27922N	Phochhu	27.92245	90.24389	0.046	5106.5043		2021
122	Pho_gl 117	G090245E27983N	Phochhu	27.98271	90.24467	0.175	5086.7060		2021
123	Pho_gl 125	G090245E27956N	Phochhu	27.95642	90.24465	0.096	5138.5371		2021

124	Pho_gl 160	G090246E27848N	Phochhu	27.84798	90.24605	0.092	4794.2659		2021
125	Pho_gl 128	G090249E27938N	Phochhu	27.93848	90.24861	0.024	5110.2017		2021
126	Pho_gl 127	G090249E27941N	Phochhu	27.94099	90.24922	0.016	5131.7925		2021
127	Pho_gl 93	G090247E28107N	Phochhu	28.10705	90.24734	1.311	4369.6644	Rapstreng	2021
128	Pho_gl 163	G090253E27841N	Phochhu	27.84140	90.25301	0.080	4987.1665		2021
129	Pho_gl 141	G090252E27897N	Phochhu	27.89707	90.25218	0.084	5153.7910		2021
130	Pho_gl 120	G090252E27960N	Phochhu	27.95973	90.25164	0.023	5174.0302		2021
131	Pho_gl 161	G090255E27847N	Phochhu	27.84665	90.25489	0.027	4862.5148		2021
132	Pho_gl 121	G090253E27956N	Phochhu	27.95636	90.25284	0.021	5172.7406		2021
133	Pho_gl 134	G090259E27925N	Phochhu	27.92538	90.25896	0.112	5120.0668		2021
134	Pho_gl 123	G090255E27953N	Phochhu	27.95289	90.25531	0.148	5208.4491		2021
135	Pho_gl 124	G090257E27943N	Phochhu	27.94276	90.25671	0.058	5198.3799		2021
136	Pho_gl 162	G090259E27843N	Phochhu	27.84346	90.25861	0.073	5017.6680		2021
137	Pho_gl 119	G090259E27957N	Phochhu	27.95699	90.25913	0.019	5197.4656		2021
138	Pho_gl 112	G090261E27996N	Phochhu	27.99603	90.26113	0.167	5157.2726		2021
139	Pho_gl 118	G090260E27964N	Phochhu	27.96414	90.26003	0.470	5208.6979		2021
140	Pho_gl 101	G090263E28059N	Phochhu	28.05880	90.26306	0.066	5111.7751		2021
141	Pho_gl 135	G090263E27920N	Phochhu	27.91987	90.26252	0.229	5139.3498		2021
142	Pho_gl 113	G090263E27988N	Phochhu	27.98796	90.26333	0.077	5200.6541		2021
143	Pho_gl 106	G090271E28029N	Phochhu	28.02897	90.27058	0.219	5201.6249		2021
144	Pho_gl 108	G090277E28008N	Phochhu	28.00838	90.27694	0.100	5281.4415		2021
145	Pho_gl 100	G090280E28050N	Phochhu	28.04961	90.27962	0.045	5056.4580		2021
146	Pho_gl 107	G090280E28013N	Phochhu	28.01288	90.27980	0.153	5283.3743		2021
147	Pho_gl 109	G090288E27997N	Phochhu	27.99657	90.28835	0.426	5326.1661		2021
148	Pho_gl 95	G090302E28093N	Phochhu	28.09280	90.30161	1.528	4509.6434	Luggye	2021
149	Pho_gl 104	G090295E28030N	Phochhu	28.03021	90.29470	0.070	5339.5863		2021
150	Pho_gl 105	G090297E28027N	Phochhu	28.02729	90.29672	0.020	5380.4000		2021
151	Pho_gl 110	G090299E27993N	Phochhu	27.99257	90.29949	0.120	5359.3877		2021
152	Pho_gl 111	G090300E27989N	Phochhu	27.98944	90.30030	0.015	5389.6118		2021
153	Pho_gl 103	G090301E28029N	Phochhu	28.02902	90.30106	0.043	5363.6019		2021
154	Pho_gl 99	G090308E28043N	Phochhu	28.04305	90.30834	0.017	5271.1628		2021
155	Pho_gl 98	G090313E28059N	Phochhu	28.05944	90.31339	0.076	5098.1631		2021
156	Pho_gl 96	G090328E28086N	Phochhu	28.08567	90.32751	0.045	4703.1031	Drukchung	2021
157	Pho_gl 92	G090231E28103N	Phochhu	28.10344	90.23080	0.420	4345.5958	Bechung	2021
158	Pho_gl 144	G090238E27891N	Phochhu	27.89129	90.23759	0.039	5009.9924		2021
159	Pho_gl 143	G090243E27897N	Phochhu	27.89703	90.24284	0.023	5145.8363		2021
160	Pho_gl 142	G090241E27899N	Phochhu	27.89909	90.24129	0.017	5169.9551		2021
161	Pho_gl 137	G090255E27916N	Phochhu	27.91611	90.25481	0.014	5198.9343		2021
162	Pho_gl 136	G090257E27918N	Phochhu	27.91842	90.25714	0.018	5189.4270		2021
163	Pho_gl 39	G089978E28056N	Phochhu	28.05626	89.97796	0.030	4990.0199		2021
164	Pho_gl 71	G090089E28116N	Phochhu	28.11593	90.08895	0.033	4491.4260		2021
165	Pho_gl 54	G090011E28123N	Phochhu	28.12270	90.01102	0.010	4703.4857		2021
166	Pho_gl 47	G089955E28104N	Phochhu	28.10429	89.95484	0.017	5133.7529		2021

Formula to Calculate GLIMS_ID in QGIS for geometry:
'G0'||to_int(x(centroid($geometry))*1000)||'E'||to_int(y(centroid($geometry))*1000)||'N'

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