The status and decadal change of glaciers in Afghanistan since 1990

Glaciers as indicators of climate change

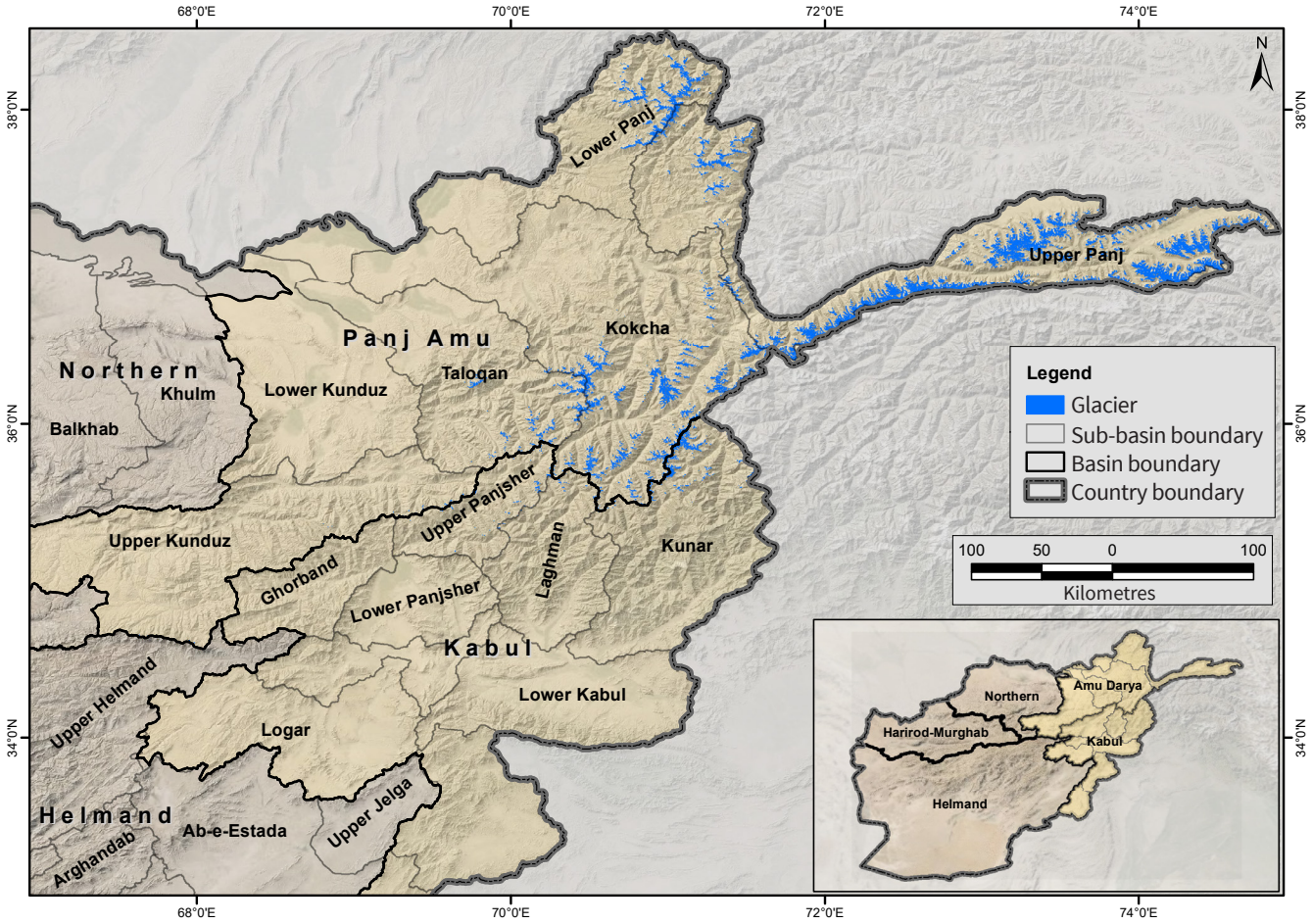
Glaciers are natural, renewable, solid reservoirs of freshwater and the only source of freshwater in the high mountains during the dry season. They are considered one of the best indicators of climate change. Their rapid melting results in new glacial lakes and causes existing ones to expand, heightening risks of glacial lake outburst floods (GLOFs). The rapid melting of glaciers can also cause freshwater shortages in the high mountains in the future. Understanding trends in how glaciers change helps us predict water availability, glacial hazards, and other impacts of climate change.

Glacier mapping methodology – Afghanistan

The glaciers in Afghanistan were mapped using Landsat satellite images from 1990, 2000, 2010, and 2015. An object-based image analysis was used to delineate the boundaries of clean-ice and debris-covered glaciers (Figure 1), which were further validated against high-resolution satellite images from Google Earth.

The glaciers equal to or larger than 0.02 km^2 were mapped with 97% accuracy. The steps are described in four ICIMOD reports: Bajracharya et al., 2011 and 2017; and Maharjan et al., 2017 and 2018. Shuttle Radar Topography Mission digital elevation model using ArcGIS software was used to determine area, aspect, slope, elevation, and hypsography for each glacier.

FIGURE 1 **DISTRIBUTION OF GLACIERS IN AFGHANISTAN**



FACTS AND FIGURES

Afghanistan has 3,891 glaciers that cover 2,543 km^2, with estimated ice reserves of 155 km^3.

In 2015, glaciers covered about 0.4% of the total land area.

The average glaciated area is 0.65 km^2.

G072584E36889N, covering an area of 39.36 km^2, is the largest glacier in Afghanistan and lies to the south of Pak village in the Wakhan Corridor.

Glaciers are found between 3,200 and 7,175 metres above sea level (masl).

The largest concentration of glacier area, 13% (318 km^2) of the total area, lies between 5,000 and 5,100 masl.

In 25 years (1990–2015), Afghanistan lost 406 km^2 (13.8%) of glacier area.

The biggest loss in glacier area (47 km^2) occurred between 4,900 and 5,000 masl.

Status of glaciers in Afghanistan in 2015

In total, 3,891 glaciers, covering a total area of about 2,543 km^2 (0.4% of the total land area) and with estimated ice reserves of about 155 km^3, were mapped (Table 1). It was found that the Panj Amu basin contains 96% of the total glacier area, while the Kabul basin contains the rest. The Upper Panj sub-basin in the Panj Amu basin alone contains about 72.5% of total glacier area and also has the highest concentration of glaciers and the largest glacier (G072584E36889N with an area of 39.36 km^2) located south of Pak village in the Wakhan corridor.

The average glacier area ranges from 0.21 km^2 to 0.81 km^2 in the sub-basins of Panj Amu and Kabul basins of Afghanistan. The average glacier area is highest in the Upper Panj sub-basin and lowest in the Kunduz sub-basin.

The glaciers are located at 3,200 masl to 7,175 masl, with the highest and lowest glaciers both located in the Upper Panj sub-basin. In other sub-basins, glaciers are found only above 3,500 masl. The highest concentration of glacier area, 13% (318 km^2) of the total glacier area, lies between 5,000 and 5,100 masl in Afghanistan.

FIGURE 2 FLOWCHART TO MAP THE CLEAN-ICE AND DEBRIS-COVERED GLACIERS

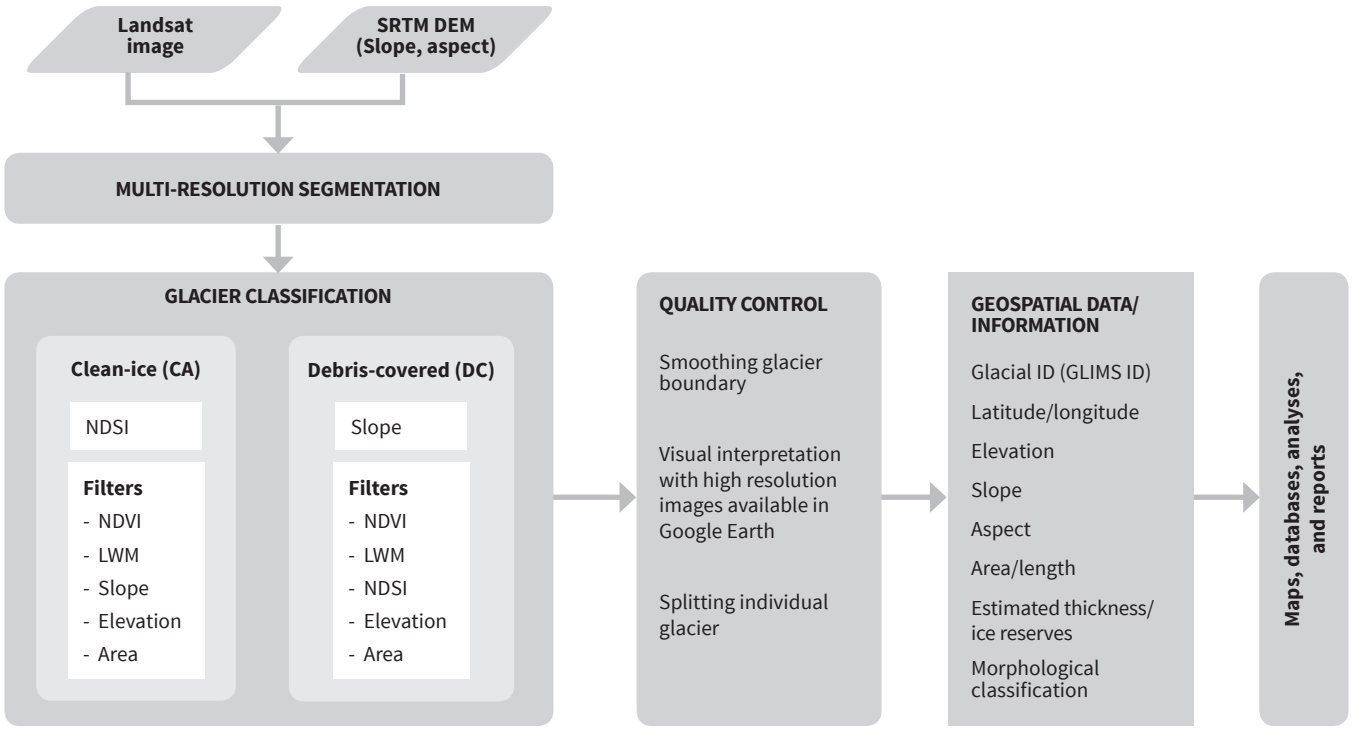


TABLE 1 DISTRIBUTION OF GLACIERS IN THE SUB-BASINS OF PANJ AMU AND KABUL IN AFGHANISTAN

Basin	Sub-basin	Number	Area (km²)		Estimated ice reserves (km³)	Elevation (masl)		Mean area (km²)
			Total	Largest		Min.	Max.	
Panj Amu	Upper Panj	1,897	1,642.25	39.36	114.205	3,201	7,175	0.87
	Lower Panj	378	197.09	4.94	8.917	3,524	5,182	0.52
	Kokcha	988	492.92	10.67	22.955	3,608	6,783	0.5
	Taloqan	253	92.85	5.77	3.917	3,668	5,746	0.37
	Upper Kunduz	62	12.97	1.33	0.355	3,783	5,050	0.21
	Total	3,578	2,438.07	39.36	150.348	3,201	7,175	0.68
Kabul	Kunar	206	86.74	9.38	4.270	3,924	6,147	0.42
	Laghman	38	5.63	1.24	0.145	4,246	5,216	0.15
	Upper Panjsher	68	12.09	2.40	0.382	3,912	5,254	0.18
	Ghorband	1	0.07	0.07	0.001	4,253	4,382	0.07
	Total	313	104.53	9.38	4.798	3,912	6,147	0.33
Total		3,891	2,542.60	39.36	155.146	3,201	7,175	0.65

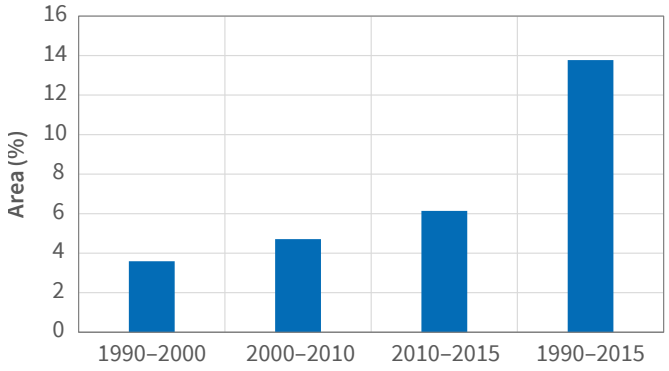
Decadal glacier change in Afghanistan since 1990

There is considerable evidence that glaciers have been shrinking and retreating over past decades in the Hindu Kush Himalaya. To analyse changes more accurately, a repeat glacier inventory of 1990, 2000, and 2010 was prepared for decadal glacier change analysis (Table 2).

Over 25 years (1990–2015), Afghanistan lost 406 km^2 (13.8%) of its total glacier area, with 3.6% lost between 1990 and 2000, and 4.7% between 2000 and 2010. In most sub-basins, 2–14% of glacier area was lost from 1990 to 2000 and 2–9% from 2000 to 2010. Between 2010 and 2015, 6.1% of glacier area was lost (Figure 3). The loss was highest (39.7%) in the Upper Panjsher sub-basin of Kabul and lowest (12.8%) in the Upper Panj sub-basin of the Panj Amu basin. The average glacier area in Afghanistan fell from 0.73 km^2 in 1990 to 0.65 km^2 in 2015.

Glaciers were grouped into five size classes. Over time, there were fewer glaciers in all classes except in class 1 (Table 3); the number of class 1 glaciers increased in all decades. But the size of all glaciers in all classes decreased (Figure 4), meaning that larger glaciers shrank and fragmented, increasing the number of small glaciers. Class 5 glaciers decreased in area by 57 km^2, with three of 27 glaciers reclassified to a lower class. The glacier number may increase if new glaciers are formed or existing glaciers fragment. Therefore, glacier area change is a better indicator of glacier advancement or retreat.

FIGURE 3 GLACIER AREA CHANGE IN AFGHANISTAN



The rate of loss of glacier area varies with elevation, with the highest rate at 4,700–5,200 masl. At 4,900–5,000 masl, 47 km^2 was lost. The loss was lowest above 5,500 masl (Figure 5).

Conclusion

The number of glaciers and the total area they occupy decreased between 1990 and 2010, as well as in 2015. The number of glaciers of the smallest class increased in some decades in some sub-basins because bigger glaciers shrank and fragmented. But for the most part, small glaciers, including thin perennial ice sheets, have disappeared in Afghanistan.

TABLE 2 DECADAL AREA CHANGE IN SUB-BASINS OF PANJ AMU AND KABUL IN AFGHANISTAN

Basin	Sub-basin	Area (km^2)				Area change (%)			
		1990	2000	2010	2015	90-00	00-10	10-15	90-15
Panj Amu	Upper Panj	1,858.95	1,803.05	1,706.45	1,642.25	-3.0	-5.4	-3.8	-11.7
	Lower Panj	250.59	225.56	206.3	197.09	-10.0	-8.5	-4.5	-21.3
	Kokcha	577.20	562.01	551.15	492.92	-2.6	-1.9	-10.6	-14.6
	Taluqan	112.10	109.68	106.75	92.85	-2.2	-2.7	-13.0	-17.2
	Kunduz	18.02	16.87	15.96	12.97	-6.4	-5.4	-18.7	-28.0
	Sub-total	2,816.86	2,717.17	2,586.61	2,438.07	-3.5	-4.8	-5.7	-13.4
Kabul	Kunar	102.97	100.33	97.45	86.73	-2.6	-2.9	-11.0	-15.8
	Laghman	8.74	7.96	7.94	5.63	-8.9	-0.3	-29.1	-35.6
	Upper Panjsher	20.10	17.33	16.98	12.09	-13.8	-2.0	-28.8	-39.9
	Ghorband	0.09	0.09	0.06	0.07	0.0	33.3	16.7	-22.2
	Sub-total	131.90	125.72	122.43	104.53	-4.7	-2.6	-14.6	-20.8
Total		2,948.76	2,842.89	2,709.04	2,542.60	-3.6	-4.7	-6.1	-13.8

FIGURE 4 GLACIER NUMBER AND CHANGES IN GLACIER AREA CLASSES FROM 1990 TO 2015

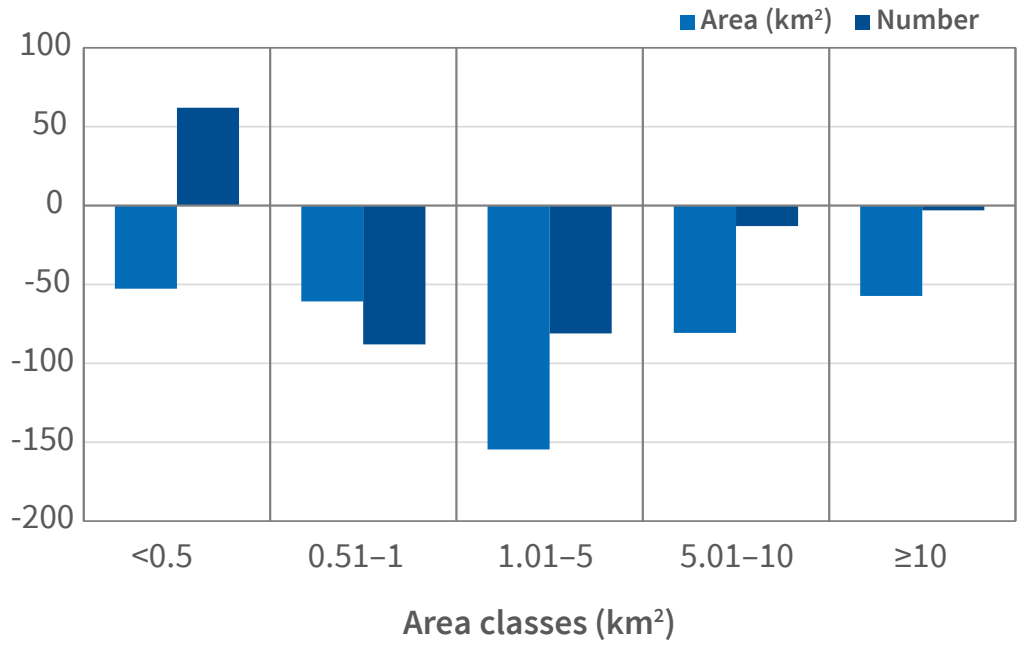


FIGURE 5 HYPSOGRAPH OF DECADAL GLACIER AREA CHANGE FROM 1990 TO 2015

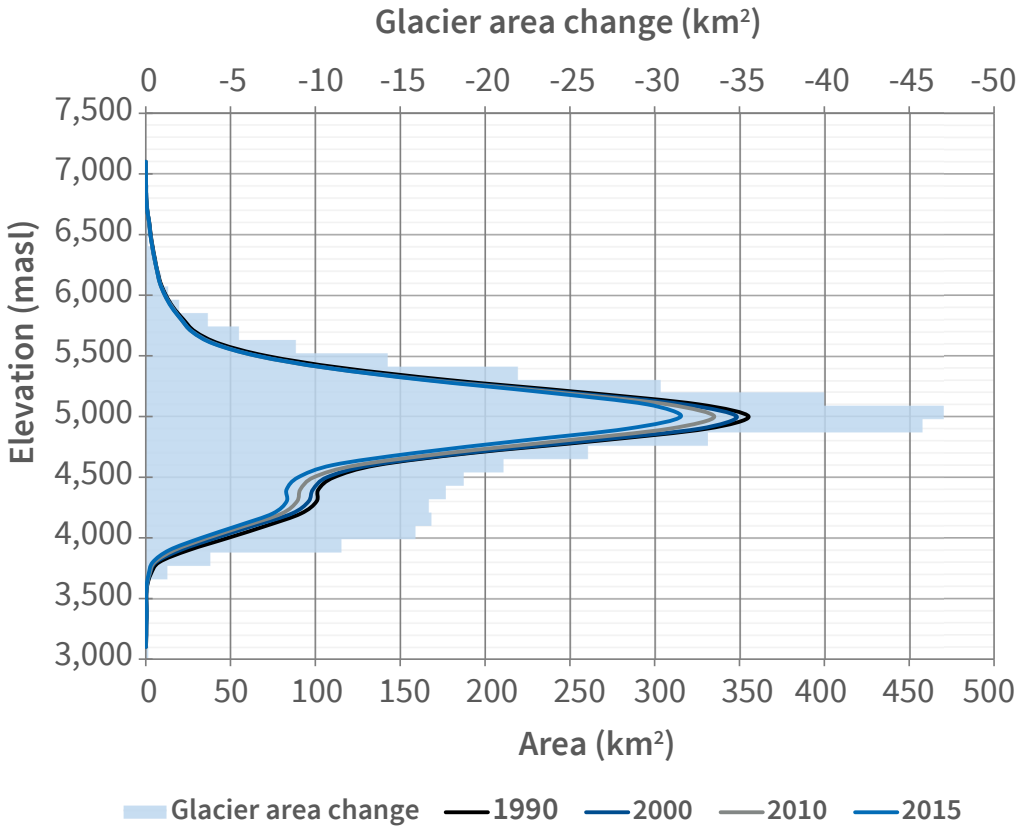


TABLE 3 NUMBER AND AREA OF GLACIER CLASSES IN AFGHANISTAN

Year	Class 1 (<0.5)		Class 2 (0.51–1)		Class 3 (1.01–5)		Class 4 (5.01–10)		Class 5 (>10)	
	Number	Area (km²)	Number	Area (km²)	Number	Area (km²)	Number	Area (km²)	Number	Area (km²)
2015	2832	475.72	502	352.76	489	990.53	44	304.46	24	419.14
2010	2814	515.34	546	386.58	516	1056.25	44	303.25	26	447.63
2000	2772	514.10	574	401.64	551	1100.40	54	366.81	26	459.93
1990	2770	528.41	590	413.52	570	1145.19	57	385.17	27	476.46
1990–2015	62	-52.69	-88	-60.75	-81	-154.66	-13	-80.71	-3	-57.32

Further reading

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