Surface areas of altitudinal zones on sub-Antarctic Marion Island

K. I. Meiklejohn[1] and V. R. Smith[2]

(1) Department of Geography, Geoinformatics and Meteorology, **University of Pretoria**, Pretoria, 0002, South Africa

(2) Department of Botany and Zoology, Stellenbosch University, Private Bag X1, Matieland, 7602, South Africa

K. I. Meiklejohn
Email: ian.meiklejohn@up.ac.za

Without Abstract

French and Smith (*1985*) used climatic, edaphic and vegetation information in an ordinal comparison to define the position of sub-Antarctic islands in the "tundra spectrum". They showed that sub-Antarctic islands possess almost the full range of vegetation types found in Northern Hemisphere tundra. A particularly significant finding concerned how altitude influenced the islands' climatic and edaphic regimes and their vegetation:
"The overall position of the sub-Antarctic islands in the tundra spectrum can be expressed by the altitudinal change needed to go from the lowest altitude "tundra vegetation", usually meadow or mire, to fellfield (or equivalent)—i.e. the increase in altitude required for the elimination of all other vegetation types. In the Northern Hemisphere sites, this is 1–2 m in the high Arctic, 2–20 m in low-Arctic and more severe Sub-arctic sites, 20–200 m in the milder Sub-arctic/Sub-alpine areas, and up to 1,000 m or more in cool-temperate and temperate alpine zones. In the southern islands, the equivalent vegetation change takes 5–50 m, while a further change of 50–500 m eliminates all plants, except scattered short grasses and cushion-forming forbs, and cryptogams" (French and Smith *1985*).

Thus, altitude strongly influences vegetation and soils at sub-Antarctic islands, as much as it does at the more climatically extreme Northern Hemisphere tundras that occur at 20–30° higher latitudes than any of the islands.

On Marion Island (47°S, 38°E), altitude is a particularly important determinant of many of the abiotic and biotic components of the ecosystem; e.g. the composition and nutrient status of the island's terrestrial habitats (Smith et al. *2001*), distribution and densities of the soil fauna (Barendse et al. *2002*), densities and activities of soil microbial populations (French and Smith *1986*; Grobler et al. *1987*), and functional processes such as decomposition (Smith et al. *1993*) and soil respiration rate (Smith *2003*). The frequency

of diurnal freeze-thaw events in the soil and the depth of freezing both increase sharply with altitude (Boelhouwers et al. *2003*) and are crucial to soil–atmosphere energy exchange, trophodynamics and nutrient cycling. Research at the island is increasingly focussing on incorporating all this structural and functional information into models and we anticipate that the models will need altitudinal spatial information. Here, we provide estimates of the areas occupied in 20 and 100 m altitudinal bands on the island.

Projected surface areas and actual surface areas were calculated using a 20 m resolution digital elevation model (DEM), developed from data supplied by the Chief Directorate: Surveys and Mapping, Mowbray, South Africa. Vector contours (10 m intervals), spot heights and drainage lines were used to interpolate the 20 m DEM using the "Topo to Raster" module in ArcGIS® (ArcInfo®).[1] The DEM was analysed using the Spatial Analyst® extension of ArcGIS®. [1] The DEM was then classified into 20 m altitudinal bands and the projected surface area (i.e. planimetric area, based on a Transverse Mercator projection) calculated from the number of raster pixels in each band and the pixel resolution (20 m × 20 m). Actual surface areas (the ground surface area) were calculated using the raster-based method of Jenness (*2004*). The results are presented in Table 1.

Table 1 Projected and actual surface areas in 20 and 100 m altitudinal bands on Marion Island

Altitude (m)	Projected area (m^2)	Surface area (m^2)	Altitude (m)	Projected area (m^2)	Surface area (m^2)
0–20	6,754,800	6,867,700	0–100	67,653,200	68,713,900
20–40	17,334,000	17,543,900	100–200	39,524,400	40,914,440
40–60	18,920,400	19,158,400	200–300	34,694,800	35,975,930
60–80	14,223,600	14,457,000	300–400	30,002,800	31,082,480
80–100	10,420,400	10,686,900	400–500	27,155,200	28,147,240
100–120	8,566,400	8,848,660	500–600	22,970,800	23,915,090
120–140	8,091,200	8,365,930	600–700	20,347,200	21,209,590
140–260	8,142,000	8,428,850	700–800	15,372,400	16,118,600
160–180	7,144,000	7,416,030	800–900	12,128,000	12,713,060
180–200	7,580,800	7,854,970	900–1,000	9,397,600	9,889,450
200–220	7,542,400	7,805,770	1,000–1,100	7,201,600	7,610,330
220–240	6,972,400	7,229,290	1,100–1,200	3,696,000	3,930,286
240–260	6,858,000	7,112,790	>1,200	181,600	197,220
260–280	6,702,400	6,954,390			
280–300	6,619,600	6,873,690			
300–320	6,075,200	6,314,580			
320–340	6,290,800	6,513,340			

Altitude (m)	Projected area (m^2)	Surface area (m^2)	Altitude (m)	Projected area (m^2)	Surface area (m^2)
340–360	6,525,200	6,732,920			
360–380	5,802,000	6,005,340			
380–400	5,309,600	5,516,300			
400–420	5,933,600	6,137,650			
420–440	6,282,800	6,483,160			
440–460	5,394,000	5,594,830			
460–480	5,041,600	5,237,590			
480–500	4,503,200	4,694,010			
500–520	4,769,200	4,951,830			
520–540	4,499,200	4,685,660			
540–560	4,884,400	5,074,720			
560–580	4,485,600	4,680,200			
580–600	4,332,400	4,522,680			
600–620	4,332,400	4,510,560			
620–640	4,512,400	4,687,980			
640–660	4,151,200	4,323,910			
660–680	3,681,600	3,854,120			
680–700	3,669,600	3,833,020			
700–720	3,434,400	3,596,430			
720–740	3,312,400	3,466,610			
740–760	2,938,800	3,087,580			
760–780	2,955,600	3,098,800			
780–800	2,731,200	2,869,180			
800–820	2,945,600	3,074,190			
820–840	2,682,800	2,803,600			
840–860	2,408,000	2,524,110			
860–880	2,187,200	2,296,050			
880–900	1,904,400	2,015,110			
900–920	2,001,600	2,107,790			
920–940	1,880,800	1,986,780			
940–960	1,802,400	1,903,450			
960–980	2,116,000	2,207,450			
980–1,000	1,596,800	1,683,980			

Altitude (m)	Projected area (m^2)	Surface area (m^2)	Altitude (m)	Projected area (m^2)	Surface area (m^2)
1,000–1,020	1,466,000	1,555,350			
1,020–1,040	1,680,400	1,769,590			
1,040–1,060	1,357,600	1,440,190			
1,060–1,080	1,410,000	1,484,510			
1,080–1,100	1,287,600	1,360,690			
1,100–1,120	1,104,000	1,162,540			
1,120–1,140	916,400	966,205			
1,140–1,160	806,000	857,787			
1,160–1,180	578,000	621,689			
1,180–1,200	291,600	322,065			
1,200–1,220	152,800	165,925			
1,220–1,240	28,800	31,295			
Total island	290,325,600	300,417,616			

References

Barendse J, Mercer RD, Marshall DJ, Chown SL (2002) Habitat specificity of mites on sub-Antarctic Marion Island. Environ Entomol 31:612–625

Boelhouwers J, Holness S, Sumner P (2003) The maritime Subantarctic: a distinct periglacial environment. Geomorphology 52:39–55

French DD, Smith VR (1985) A comparison between Northern and Southern Hemisphere tundras and related ecosystems. Polar Biol 5:5–21

French DD, Smith VR (1986) Bacterial populations in soils of a sub-Antarctic Island. Polar Biol 6:75–82

Grobler DC, Toerien DF, Smith VR (1987) Bacterial activity in soils of a sub-Antarctic Island. Soil Biol Biochem 19:485–490

Jenness JS (2004) Calculating landscape surface area from digital elevation models. Wildl Soc Bull 32:829–839
<Occurrence Type="DOI"><Handle>10.2193/0091-7648(2004)032[0829:CLSAFD]2.0.CO;2</Handle></Occurrence>

Smith VR (2003) Soil respiration and its determinants on a sub-Antarctic island. Soil Biol Biochem 35:77–91

Smith VR, Steenkamp M, French DD (1993) Soil decomposition potential in relation to environmental factors on Marion Island (sub-Antarctic). Soil Biol Biochem 25:1619–1633

Smith VR, Steenkamp M, Gremmen NJM (2001) Terrestrial habitats on sub-Antarctic Marion Island: their vegetation, edaphic attributes, distribution and response to climate change. S Afr J Bot 67:641–654

Footnotes

[1] ArcGIS, ArcInfo and Spatial Analysis are registered trademarks of Environmental Systems research Institute, Inc., Redlands, CA, USA.