Cost Raster Creation Worklfow

2023-04-05

Data Sources

DEM from OpenTopography STRM15+ 450m resolution, coord system: WGS84 (ESPG:4326), units:meter https://portal.opentopography.org/raster?opentopoID=OTSRTM.122019.4326.1

Tozer, B, Sandwell, D. T., Smith, W. H. F., Olson, C., Beale, J. R., & Wessel, P. (2019). Global bathymetry and topography at 15 arc sec: SRTM15+. Distributed by OpenTopography. https://doi.org/10.5069/G92R3PT9. Accessed: 2022-10-26

Climate data from pastclim R package https://rdrr.io/github/EvolEcolGroup/pastclim/

Leonardi, M., Hallett, E. Y., Beyer, R., Krapp, M. & Manica, A. pastclim: an R package to easily access and use paleoclimatic reconstructions. 2022.05.18.492456 Preprint at https://doi.org/10.1101/2022.05.18.492456 (2022).

Glacier extents from Batchelor et al 2019 https://osf.io/7jen3/

Batchelor, C.L., Margold, M., Krapp, M. et al. The configuration of Northern Hemisphere ice sheets through the Quaternary. Nat Commun 10, 3713 (2019). https://doi.org/10.1038/s41467-019-11601-2

Modern rivers and lakes from HydroSheds https://www.hydrosheds.org/products

Messager, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O. (2016). Estimating the volume and age of water stored in global lakes using a geo-statistical approach. Nature Communications, 7: 13603. https://doi.org/10.1038/ncomms13603

Lehner, B., Grill G. (2013). Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. https://doi.org/10.1002/hyp.9740

Modern oceans from Marine Regions https://www.marineregions.org/downloads.php

Flanders Marine Institute (2018). IHO Sea Areas, version 3. Available online at https://www.marineregions.org/https://doi.org/10.14284/323

Calculating slope cost from DEM

1. calculate the slope of the terrain from the DEM
2. use Raster Calculator to calculate the Llobera & Sulkin walker cost via the following function

$Cost(s) = 2.635 + 17.37s + 42.37s^2 - 21.43s^3 + 14.93s^4$

where s is the mathematical slope of the DEM (s = slope percentage/100)

Stage	Water amount	Black Sea level (masl)	Caspian Sea level (masl)	Aral Sea level (masl)	Kara Sea level (masl)	Other levels
MIS 3	~	-25	-140	57	0	
MIS 4	low	-25	-140	57	45	Barents Sea: 40 masl, White Sea: 45 masl
MIS 4	high	~	~	57	45	Barents Sea: 40 masl, White Sea: 45 masl; Dnieper River: 30 masl
MIS 5a	~	6	-5	57	-30	White Sea: 12 masl
MIS 5b	low	~	~	70	1	Ob River: 60 masl, Yenissei River: 70 masl
MIS 5b	high	~	~	70	1	White Sea: 126 masl; Ob River: 90 masl
MIS 5c	~	6	-5	57	-25	
MIS 5d	low	26	~	57	~	Ob River: 60 masl, Yenissei River: 70 masl
MIS 5d	high	~	~	70	~	Barents Sea: 100 masl
MIS 5e	~	6	-5	57	0	
MIS 6	low	6	10	57	60	
MIS 6	high	6	10	57	120	

Creating desert rasters

1. use get-climate-data.R script to produce tiff files for average annual precipitation
2. reclassify each precipitation raster to 1 if annnual precipitation is less than 250mm

Creating ice rasters

1. pull ice estimate shapefile to QGIS
2. pull DEM into QGIS
3. clip ice shapefile using the DEM extent
4. clip the DEM by mask layer using the clipped shape file
5. fill NODATA cells of clipped DEM with unique no data value (i.e. 999999 used for this study)
6. raster calculator on new raster such that where values are not the no data value set them to impassable value (i.e. -999999 used for this study)

Creating lake rasters via lake flooding

1. find shapefiles for lake extents for all lakes that will be flooded
2. reproject lake shapefile to be in same projection as DEM
3. use SAGA Clip raster with polygon to clip the DEM
4. use Raster Calculator to multiply all cells with values in the clipped raster by the level you want to flood to (raster >= -99999 (or another null value)) * lake level)

- MAKE SURE TO SET EXTENT TO OVERALL DEM

5. use SAGA Lake Flood to create Surface layer
6. reclassify the surface raster so that cells with values equal to the desired lake level are coded as 1 and all others are 0

For our analysis we used the following lake levels:

We also included modern lakes that had a volume greater than or equal to 1 cubic kilometer. These modern lakes were saved as a separate known lakes raster where cells with lakes were coded as 1 and all others were coded as 0. Modern oceans that were not subjected to the above flooding procedure were also included.

Creating river raster

1. calculate river width using Moody and Troutman equation (2002)
2. create variable distance buffer around rivers by river width variable
3. rivers are split into impassable and passable rivers; impassable rivers are those with a width greater than 1 kilometer
4. for both impassable and passable rivers, clip DEM raster by buffered river polygons
5. for both impassable and passable rivers, reclassify raster from step #4 so that areas where the polygons were are equal to 1

Creating cost rasters

The following process was done for each of the Marine Isotope Stages and water amounts as shown in the table above.

1. using the Raster Calculator, multiple the slope cost by the desert raster

- for this study, we increased the cost of desert squares by 74%
- $if(desert = 1, Cost(s) * 1.74, Cost(s))$

2. using the Raster Calculator, reclassify the result of step #1 with the impassable values from the ice raster

- $if(ice < 0, -999999, Cost'(s))$

4. using the Raster Calculator, reclassify the result of step #3 with the known ocean, known lake, impassable rivers rasters, and flooded rivers

- $if(oceans = 1$ OR $lakes = 1$ OR $rivers = 1$ OR ..., $-999999, Cost''(s))$
- since each flooded river is an individual raster, those will be included as separate conditions in the if statement
  - for example, \$... OR aral = 1 OR ... \$

5. using the Raster Calculator, add in the river crossing multipler to the raster from step #4

- for this study, we increased the cost of river cells by 74%
- $if(rivers = 1$ AND $Cost'''(s)! = -999999, Cost'''(s) * 1.74, Cost'''(s))$