Efficient Algorithms For Watershed Analysis

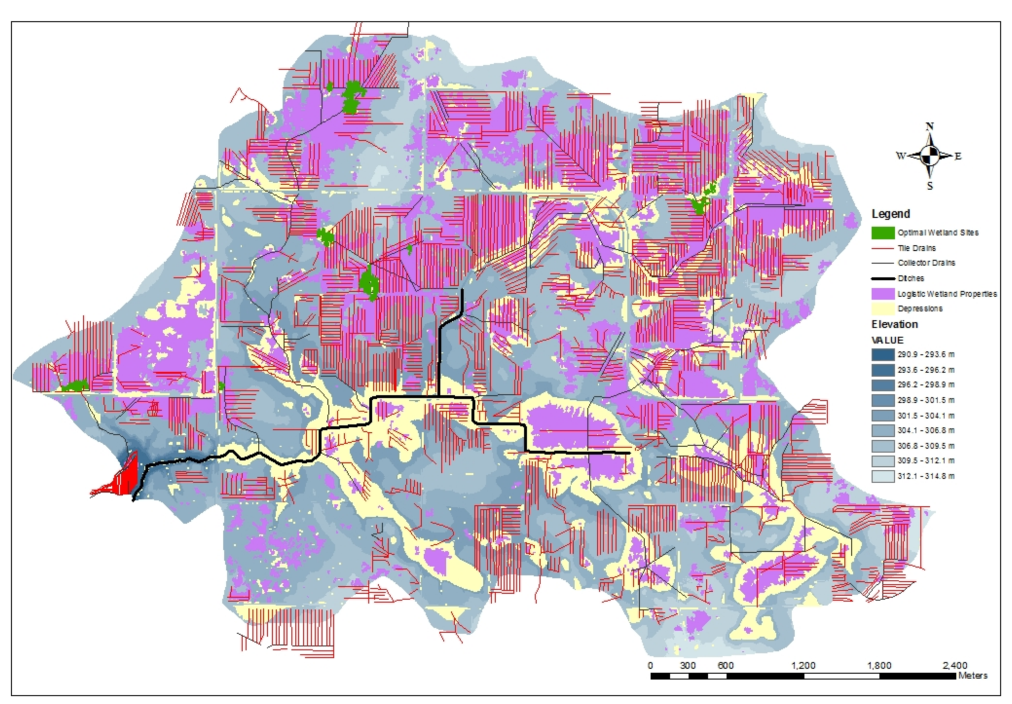
Richard Barnes

The United States is home to a vast natural watersystem of rivers and lakes. Interwoven is a large artificial system of drain tiles and ditches. The porous boundary between these systems transmits fertilizers, antibiotics, pesticides, hormones, and other chemicals. In addition, erosion may lead to topsoil loss.

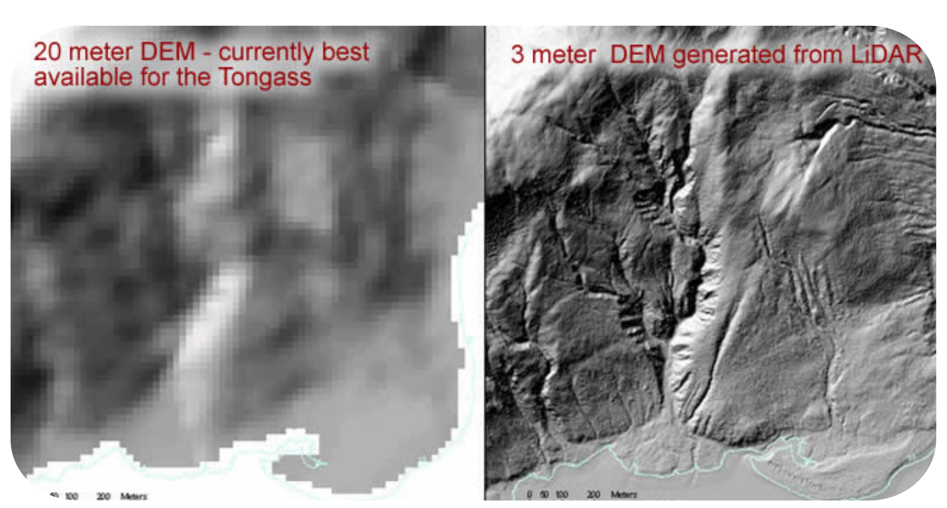
Funding for mitigation, rehabilitation, and conservation is often allocated at the state or national level, yet the system is so complex, and the data so large, that existing tools cannot analyze it at this scale.

The goal, then, is to produce new algorithms which will enable GIS tools to quickly analyze terabytes or more of data. This, in turn, will facilitate landscape optimization.

The Optimal Wetland Construction Sites in the Beauford Watershed



The resolution of DEMs is increasing



Barnes, R. 2016. Non-divergent flow accumulation for trillion cell digital elevation models on desktops or clusters. In Review.

Barnes, R. 2016. Flow accumulation is optimized. In Review.

Barnes, R. 2016. dggridR: Discrete Global Grids for R. Software: https://github.com/r-barnes/dggridR

Barnes, R. 2016. Parallel priority-flood depression filling for trillion cell digital elevation models on desktops or clusters. Computers & Geosciences. doi: 10.1016/j.cageo.2016.07.001.

Barnes, Lehman, Mulla. 2013. "An Efficient Assignment of Drainage Direction Over Flat Surfaces in

Comparison vs. Other Algorithms

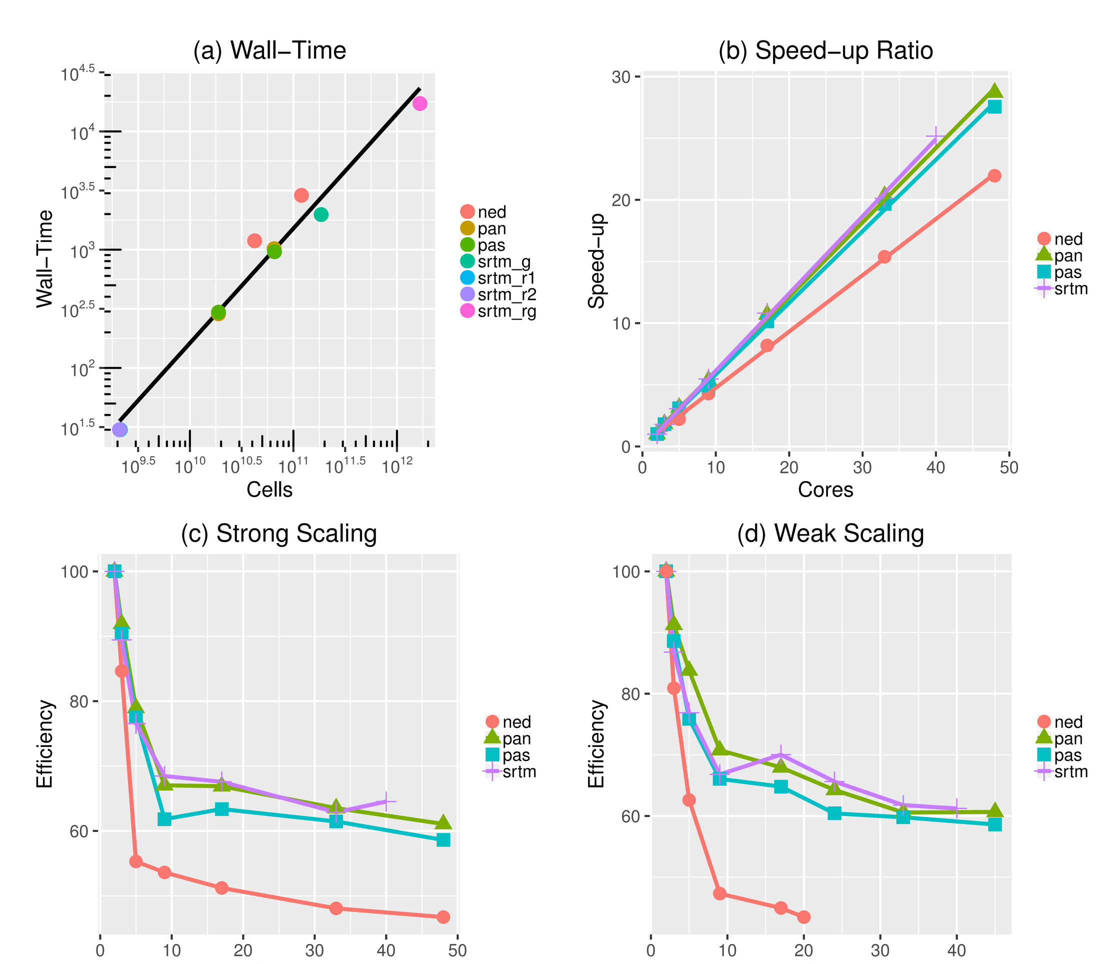
Source	Year	Cells	Resolution	Dimensions	Adjective	Time (min)	Min/Cell
This paper (RichDEM)	2016	$2 \cdot 10^{12}$	10 m	~1,291,715^2	*rather* large	287	$8 \cdot 10^{-9}$
Gomes et al. [12]	2012	$3 \cdot 10^{9}$	30 m	50,000 x 50,000	huge	58	$1 \cdot 10^{-8}$
Do et al. [8]	2010	$2 \cdot 10^{9}$	??	36,002 x 54,002	huge	21	$1 \cdot 10^{-8}$
Do et al. [9]	2011	$2 \cdot 10^{9}$	??	36,002 x 54,002	huge	??	
Yıldırım et al. [29] (TauDEM)	2015	$2 \cdot 10^{9}$	10 m	45,056 x 49,152	large	??	
Arge et al. [2] (GRASS)	2003	$1 \cdot 10^{9}$	10 m	33,454 x 31,866	massive	3720	$3 \cdot 10^{-6}$
Lindsay [16] (Whitebox GAT)	2015	$9 \cdot 10^{8}$	3 arc-sec	37,201 x 25,201	massive	8.6	$1 \cdot 10^{-8}$
Tesfa et al. [24]	2011	$6 \cdot 10^{8}$	??	24,856 x 24,000	large	20	$3 \cdot 10^{-8}$
Wallis et al. [26] (TauDEM)	2009	$4 \cdot 10^{8}$	??	14,949 x 27,174	large	8	$2 \cdot 10^{-8}$
Danner et al. [6]	2007	$3 \cdot 10^{8}$	3 m	??	massive	445	$1 \cdot 10^{-6}$
Metz et al. [19, 20] (GRASS)	2010	$2 \cdot 10^{8}$	30 m	??	massive	32	$6 \cdot 10^{-7}$

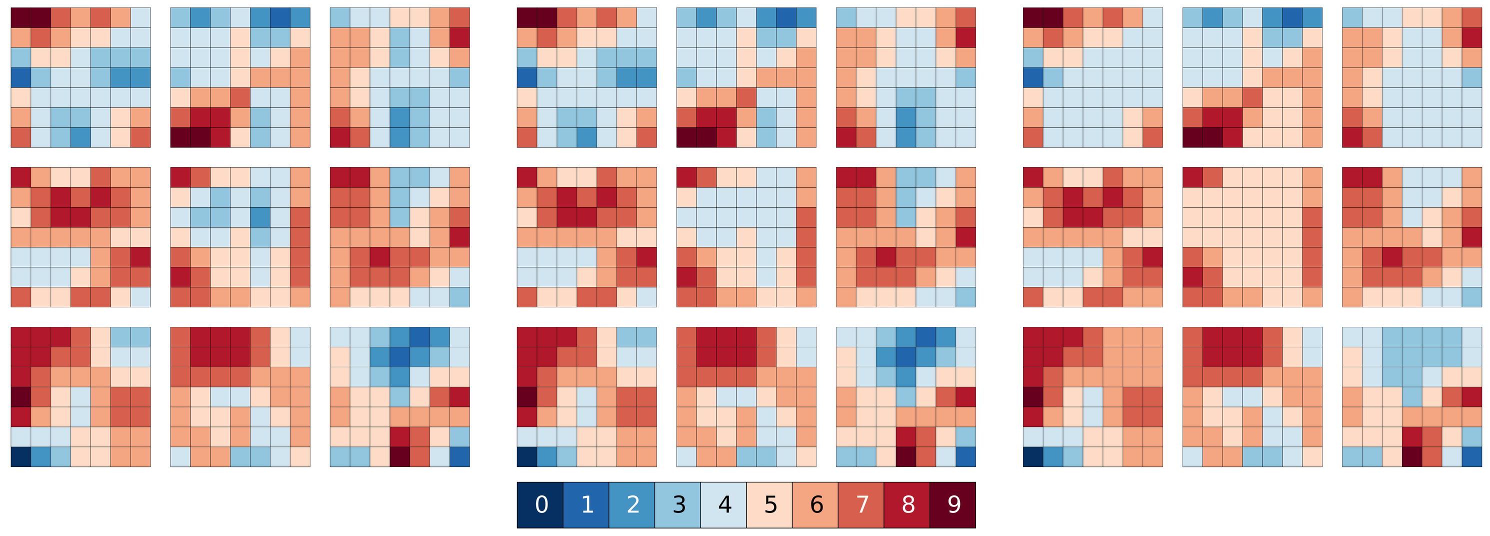
Datasets Employed

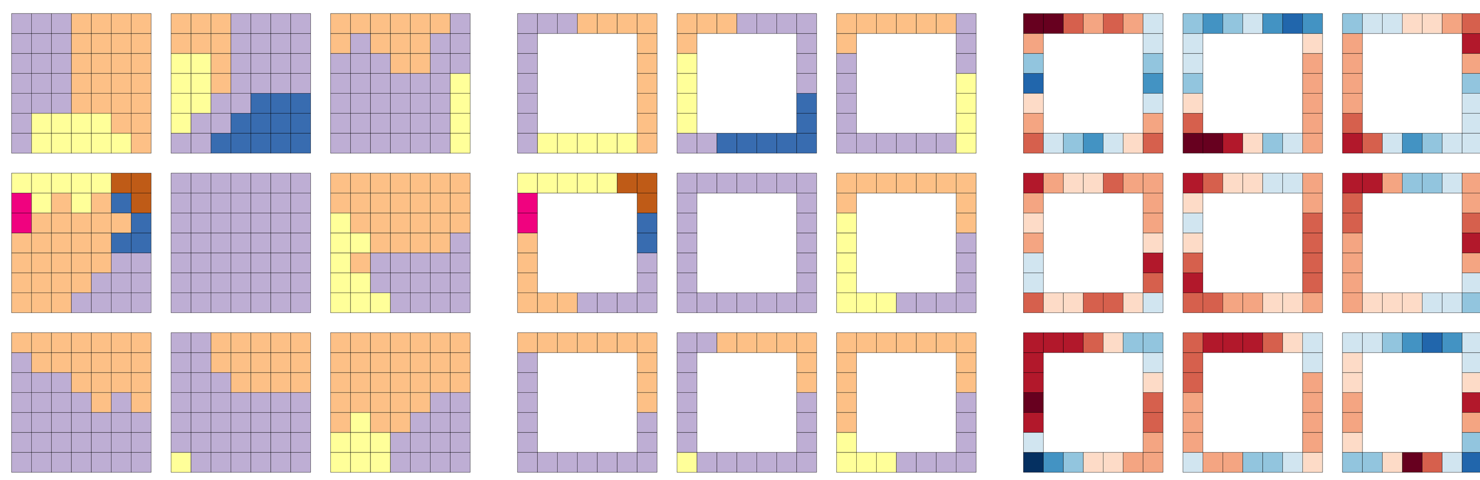
Name	Resolution	Tiles	Cells/Tile	File Size	Total Size	Cells
SRTM Resampled	10 m	14297	10803^2	233 MB	3.34 TB	$1.7 \cdot 10^{12}$
SRTM Global	30 m	14297	3601^2	26 MB	371 GB	$1.9 \cdot 10^{11}$
NED	10 m	1023	10812^2	468 MB	478 GB	$1.2 \cdot 10^{11}$
PAMAP North	1 m	6666	3125^2	39 MB	260 GB	$6.5 \cdot 10^{10}$
PAMAP South	1 m	6723	3125^2	39 MB	263 GB	$6.6 \cdot 10^{10}$
SRTM Region 1	30 m	164	3601^2	25.9 MB	4.3 GB	$2.1 \cdot 10^{9}$
SRTM Region 2	30 m	161	3601^2	25.9 MB	4.2 GB	$2.1 \cdot 10^{9}$

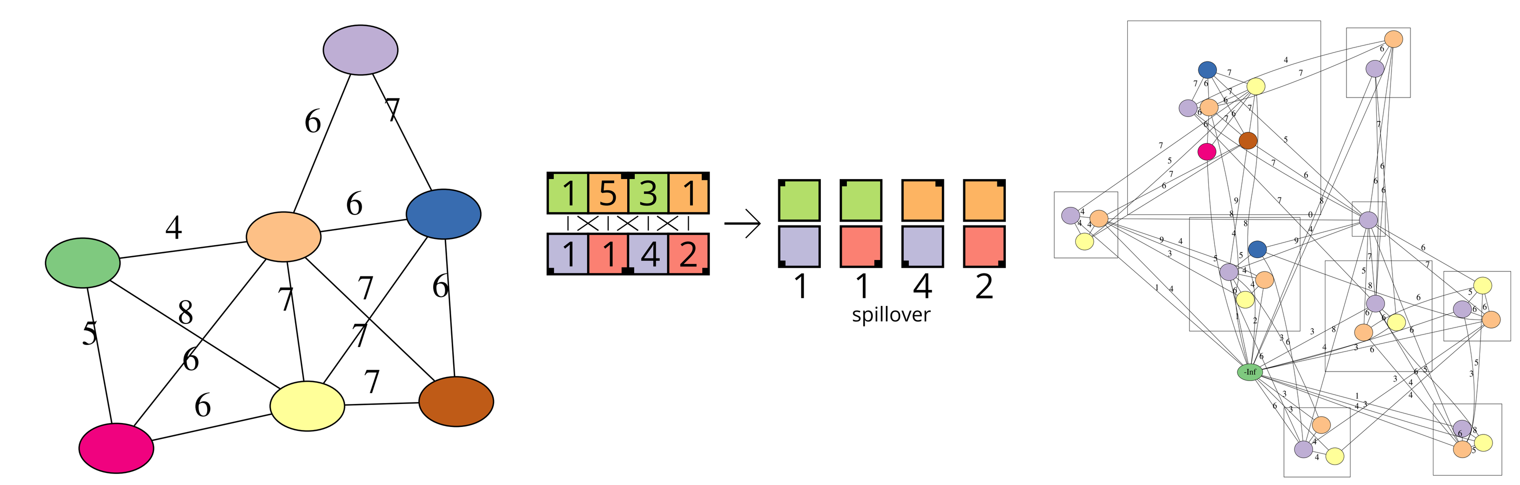
Results

DEM	Time (Min)	Sec/10^9 cells	% I/O (%)	All Time (Hrs)	Prod. Calc (Sec)	Labels	Sent (MB)	Received (MB)	Tx/Tile (KB)	Cons. VmHWM (MB)	Prod. VmPeak (MB)
SRTM Resampled	287	10	11	223	84	21,625,210	50	4,109	291	1,307	12,236
SRTM Global	33	11	8	25.5	37	11,478,908	29	1,452	104	209	6,011
NED	48	25	4	37.1	6	1,451,911	6	380	377	1,725	1,295
PAMAP North	17	15	9	12.8	12	2,384,615	12	717	109	234	1,943
PAMAP South	16	15	9	12.5	10	1,720,776	10	709	107	233	1,703
SRTM Region 1	0.5	14	3	0.32	0.3	95,106	0.3	16	99	184	478
SRTM Region 2	0.5	14	3	0.31	0.4	139,472	0.4	17	105	162	494









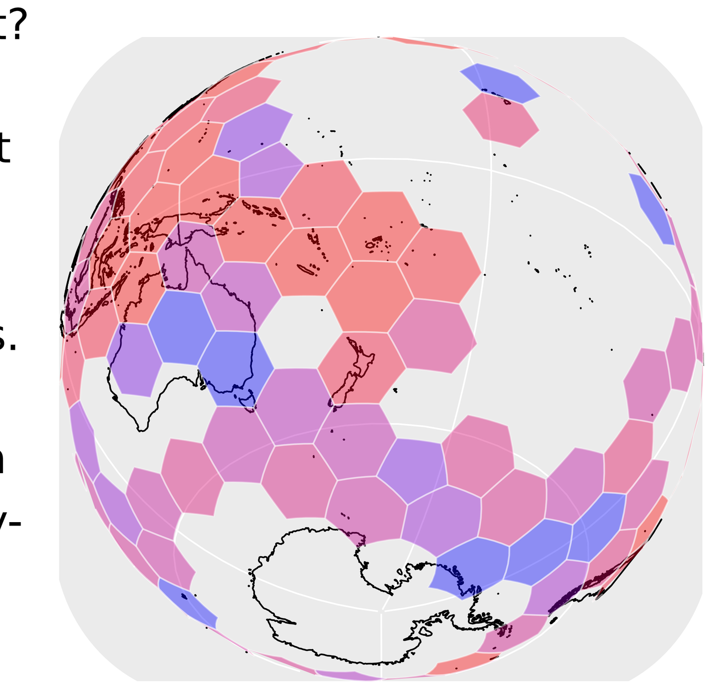
richdem.com

And another thing: dggridR

Do you remember when spatial analysis was great?

That was probably before you learned how difficult it is to put a grid of equally-sized rectangular cells on a sphere. Before you felt the terror of projections and the horror of statistical corrections.

Fortunately, I've made spatial analysis great again with an R package that divide spheres into equally-sized hexagonal cells.



Available on CRAN and at https://github.com/r-barnes/dggridR.