

VISUALIZATION OF VECTOR FIELD USING PARTICLES IN GRASS GIS

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Introduction

This project focused on the visualization of processes based on vector fields using the movement of vector particles. The resulting dynamic comet-like visualization is developed in GRASS GIS.

Methods

The visualization is based on moving particles in a vector field where the movement is driven by speed and direction of the underlying phenomenon. Particles are randomly generated and they disappear after certain time so that they can be replaced by new generated particles, keeping the number of particles constant.

Particle movement algorithm

1. Input is speed and direction raster.
2. Generate new vector with total number of points (particles) and randomly assign age to them.
3. Iterate over time with given time step:
 - (a) create new vector map by moving each point based on time step and the value extracted from speed and direction raster,
 - (b) increment age of particles,
 - (c) remove points over specified age,
 - (d) generate new points to keep the number of points constant.
4. Create a temporal dataset and register the created vectors.

Particles can be generated with different probability in different places to simulate spatially variable occurrence of a phenomenon, for example runoff changing based on land cover. The number of generated particles is not exactly equal to the specified number of particles but is close enough.

Generating random particles with spatially variable probability

1. Normalize raster to (0, 1) range.
2. Set a computational resolution based on desired number of points on grid and mean value of probability raster.
3. Generate random surface with values from 0 to 1.
4. If cell value from random raster is smaller then cell value from probability raster, write 1, otherwise null.
5. Convert resulting raster to vector map (points on grid).
6. Slightly, randomly jitter points.

A specified number of subsequent states of particles are shown together resulting in a comet-like visualization. The most recent particle is the biggest one and as particles get older, their size decreases. All particles are in one GRASS vector map, rearranged in the form that each GRASS vector layer (one vector map can have multiple layers) contains an individual step of the animation and the layers share the individual particles.

Water flow visualization

The visualization method was used to describe overland water flow. The speed was computed from the approximation of Manning formula (1), where s is slope, h is flow depth and n is manning's coefficient. The depth was computed using GRASS module *r.sim.water*.

$$v = \frac{1}{n} \sqrt[3]{h^2} \sqrt{s} \quad (1)$$

The following figure shows one snapshot from the animation of water flow in the area of Sediment and Erosion Control Research and Education Facility (SECREF), located at the Lake Wheeler Road Field Laboratory in Raleigh. We can see that particles are not generated in the forested areas because of high infiltration. The speed of particles in grassy areas is generally lower then in the fields, which is visible from the different length of the “comets” (longer in agriculture zones, shorter in grasslands).

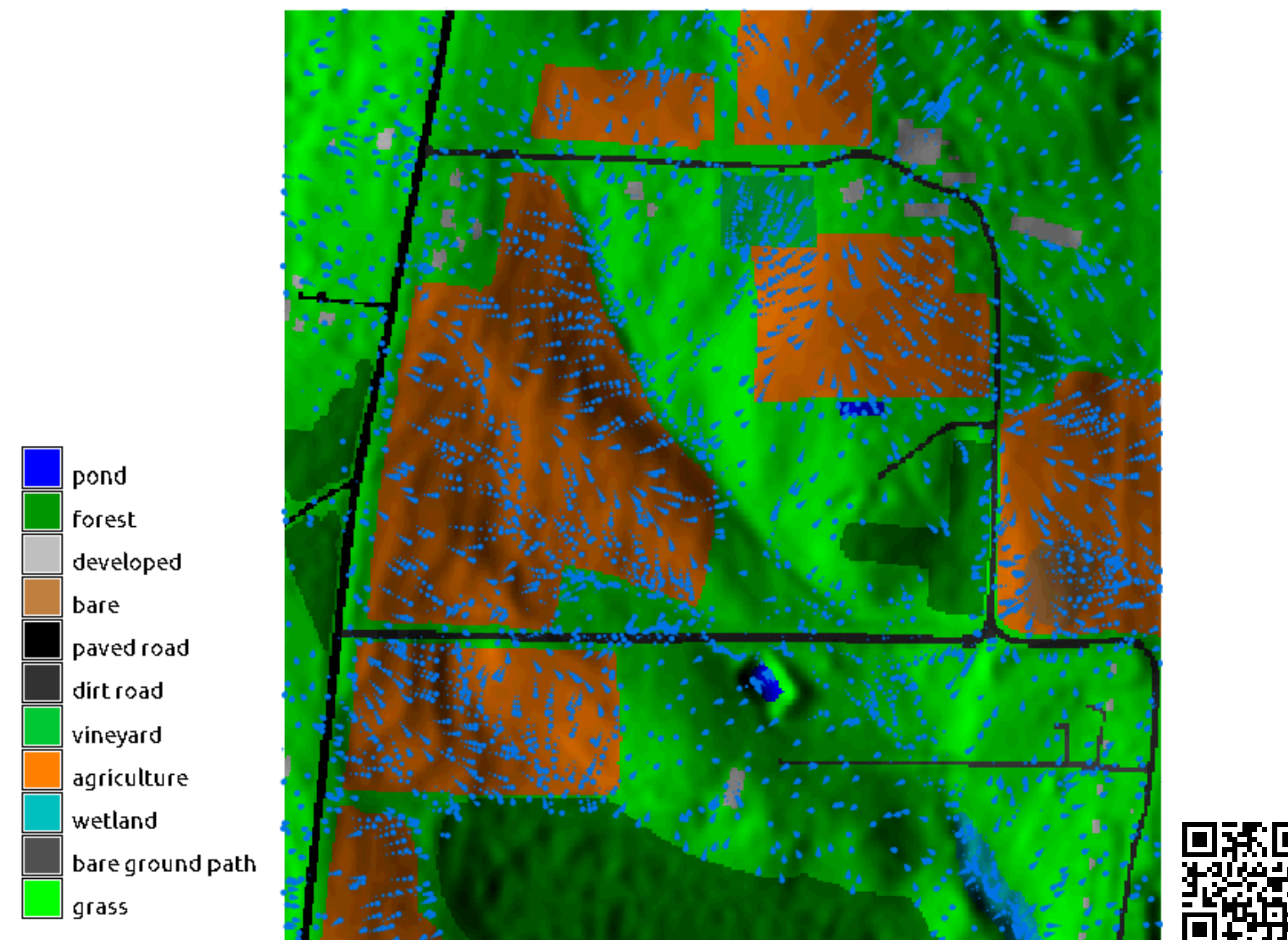
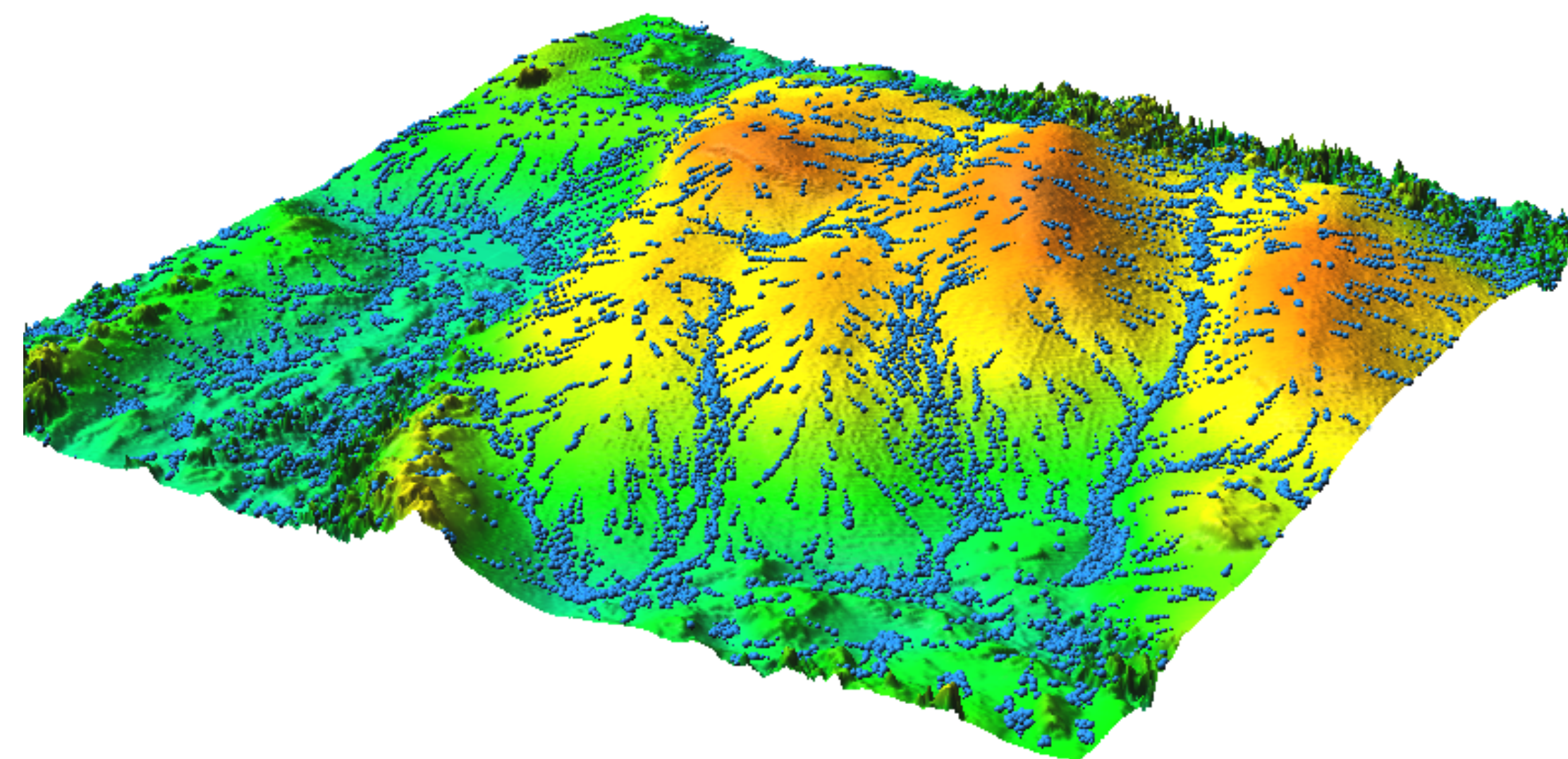


Fig. 1: Comet-like visualization of water flow with spatially variable runoff

The same visualization in 3D with uniform runoff is shown in the following figure:



Cumulative cost surface visualization

In another application, I used this visualization method to show the movement of people to a particular location along the shortest paths. The speed was derived from actual road speed limits, however I had to decrease the speed range for the purpose of the animation to avoid large differences between speed of the particles on and off roads. The direction was defined as the aspect of the cumulative cost surface representing travel time to the selected location.

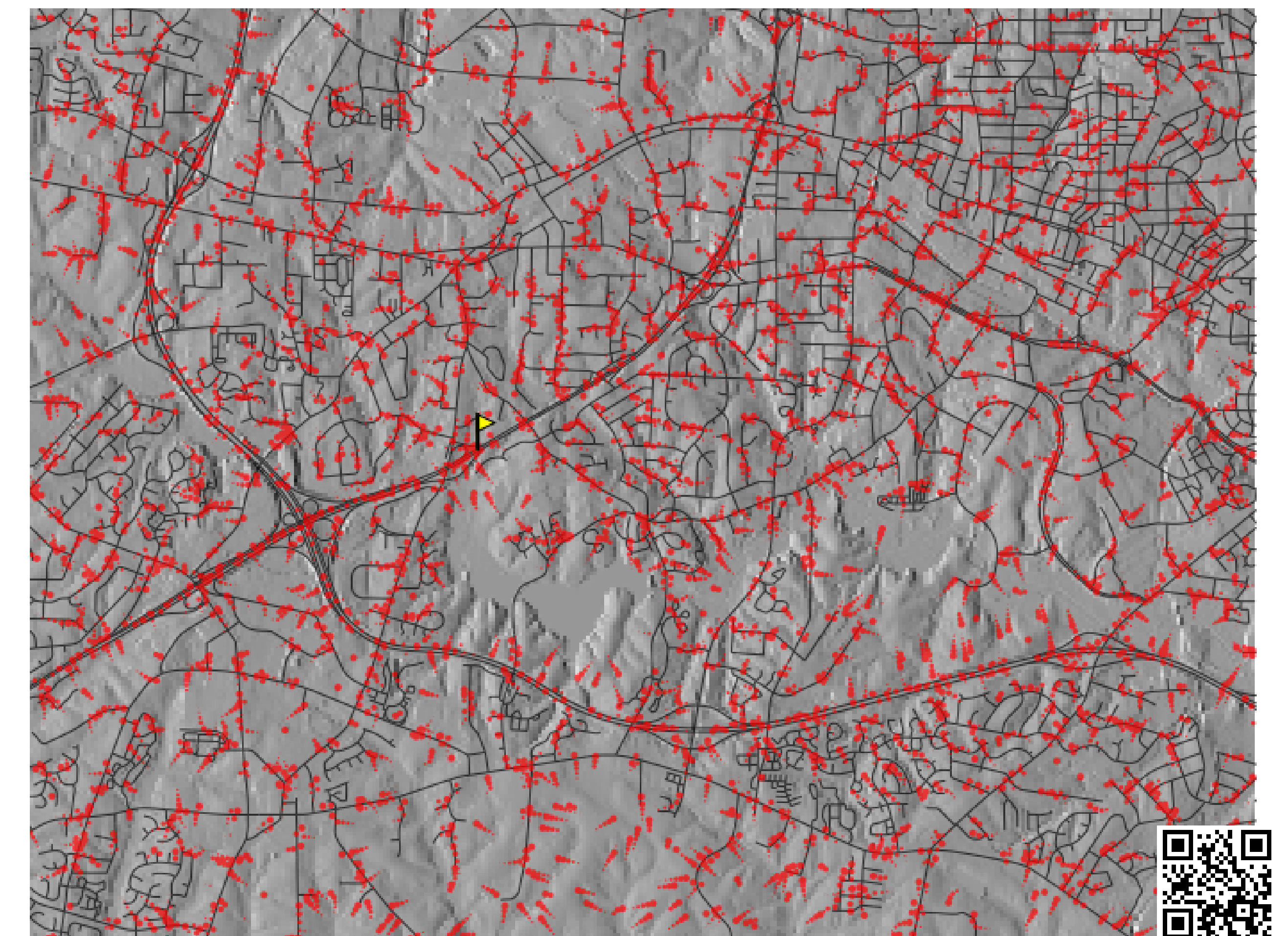


Fig. 3: People moving on a cumulative cost surface representing travel time to a location.

Results

The visualization method was implemented in GRASS GIS, as a Python script. I developed 2 modules; *v.random.probability* generates vector points with spatially variable probability, and *v.particles* outputs vector temporal datasets which can be then easily visualized in GRASS GIS Animation Tool. Animation Tool was improved during the development by adding support for an additional type of vector temporal dataset. The modules are available on public NCSU OSGeoREL github:

<https://github.com/ncsu-osgeorel/grass-particle-flow-visualization>

An example of calling the *v.particles* module:

```
v.particles aspect=aspect speed=speed particle_base=steps particles=particles
probability=probability total_time=1000 step=4 age=40 count=2000
comet_length=6
g.gui.animation
```