A GIS method for assessing the zone of human-environmental impact around archaeological sites:

A test case from the Late Neolithic of *Wadi Ziqlâb*, Jordan.

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Archaeological Catchments

- A zone around an archaeological site where the inhabitants of the site would have interacted with the environment.
- Specific catchments for specific activities.
  - Farming, herding, hunting, gathering, etc.
- Catchments are "created" by applying a set of decision-making rules to a given set of socioecological conditions.
  - If we can reconstruct ancient sociecological conditions and deduce ancient decision-making rules, the spatial pattern of ancient catchments can be modeled.

Relevance of Catchment Modeling

- Understanding ancient settlement patterns
- Studying the legacies of human use of the environment (human induced landscape change)
- Spatially explicit computational models of human/environment interaction

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- Catchment analysis is the "first step" for all of these things
  - First need to know where people were interacting with their environment in order to model those interactions

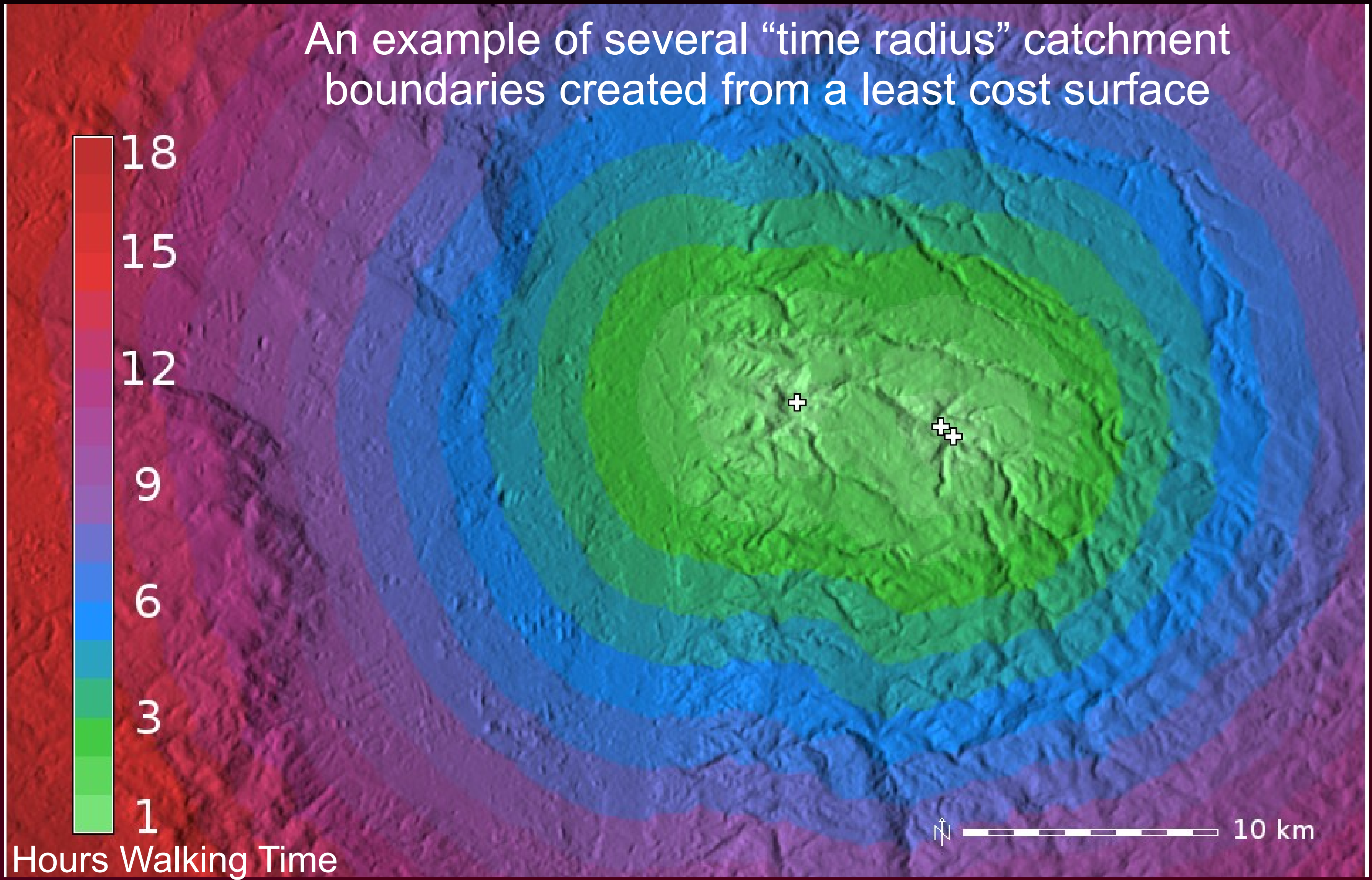
The Original Catchment Concept

- Delimited by a time radius derived from ethnographic data (walking time)
- The zone was mapped by either:
  - Walking out from the site in the four cardinal directions for a given time, charting the termini, and “visually interpolating” a connecting boundary line between them.
  - Determining a single time radius and drawing a circle of that radius centered on the site.

Original Concept - GIS Implementation

- Circular radius-buffer is the simplest method
  - Obvious problems with accuracy/usefulness
- Time-distance boundaries using least cost modeling
  - Least cost surfaces are in units of travel time.
  - Determine catchment boundary by delimiting a time-cost isohyet.
  - The resultant catchment boundaries are more realistic than circular buffers.

Anisotropic Least Cost Surface



Problems With the Original Concept

- Time radii
  - Must be determined by ethnographic modeling of travel times
    - Ethnographic averages reduce natural variability
  - Difficult to incorporate other ethnographic/economic data
    - e.g. information about the amount of land needed for farming
  - Difficult to incorporate ecological data
    - e.g. Ecological needs of herd animals
- Monolithic and Static Area
  - All parts of landscape that fall within the catchment radius are not equally used, and boundaries will fluctuate over time.
    - e.g. Farm plots require low slope areas, and change with population

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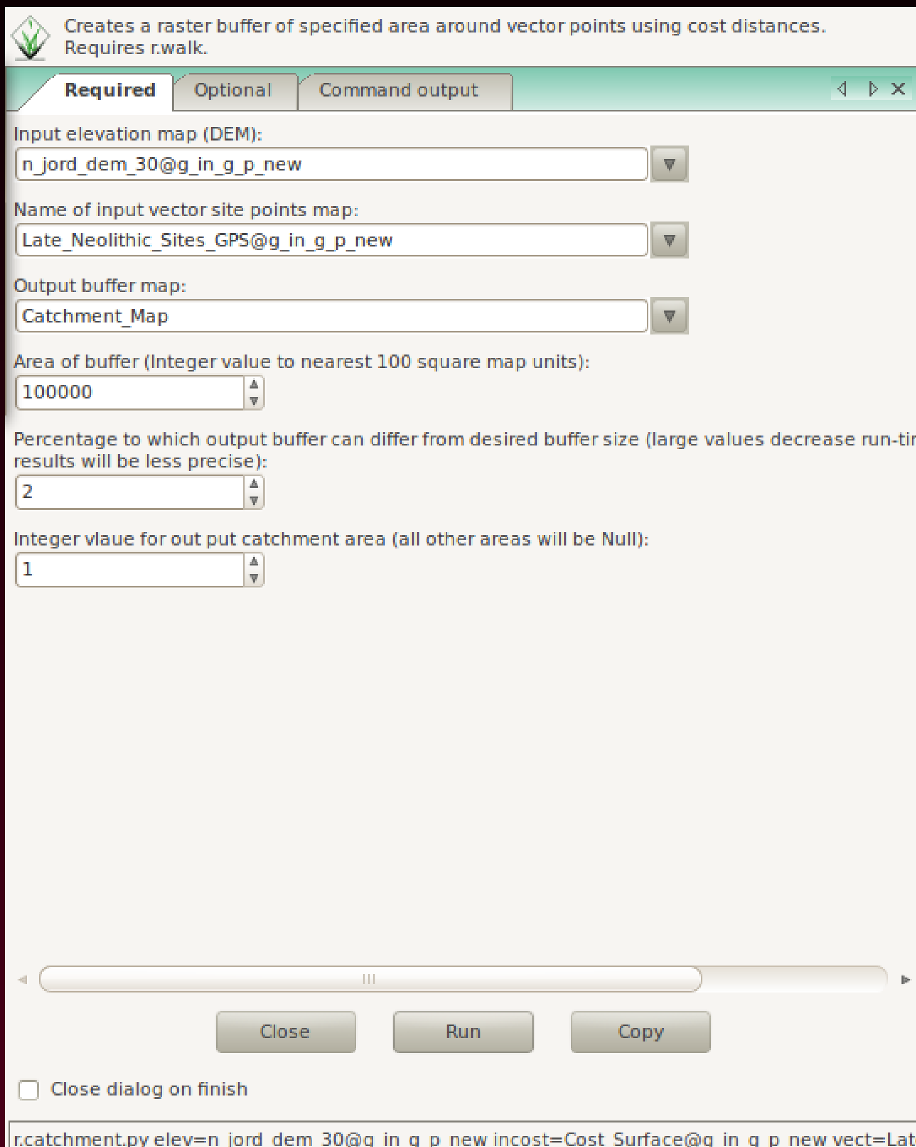
Not flexible enough for use in computational models

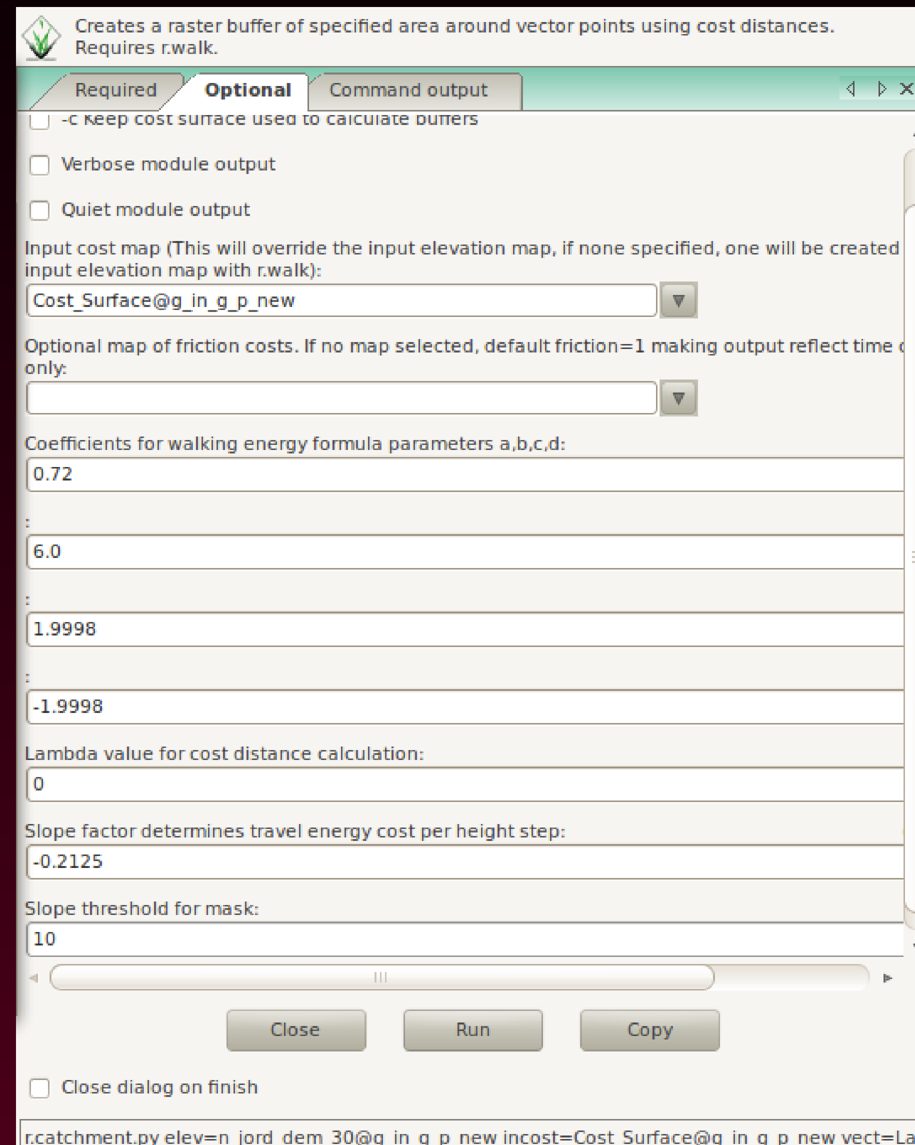
Refining the Concept of Catchment Analysis

- Incorporate area in the catchment definition routine, in addition to walking costs (time radii).
  - Catchment boundaries should be defined by the isohyet of minimum walking effort (in all directions) that encompasses the area required for a certain activity or suite of activities.
- Incorporate socioecological value of landscape patches in the catchment definition routine
  - Landscape patches (cells) should be weighted to make them more or less “attractive” to the least cost algorithm, and may even be completely ignored (left out all together) when calculating catchment geometry.

Refined Concept - GIS implementation

The “r.catchment” addon module for GRASS GIS





"r.catchment" Boundary Search Routine

<u>**Loop of Iterated Boolean Equations:**</u>

- **If:** Test Area > Desired Area

→ Hi Cutoff = (Hi Cutoff + Lo Cutoff)/2

→ Set Test Area Boundary to Hi Cutoff

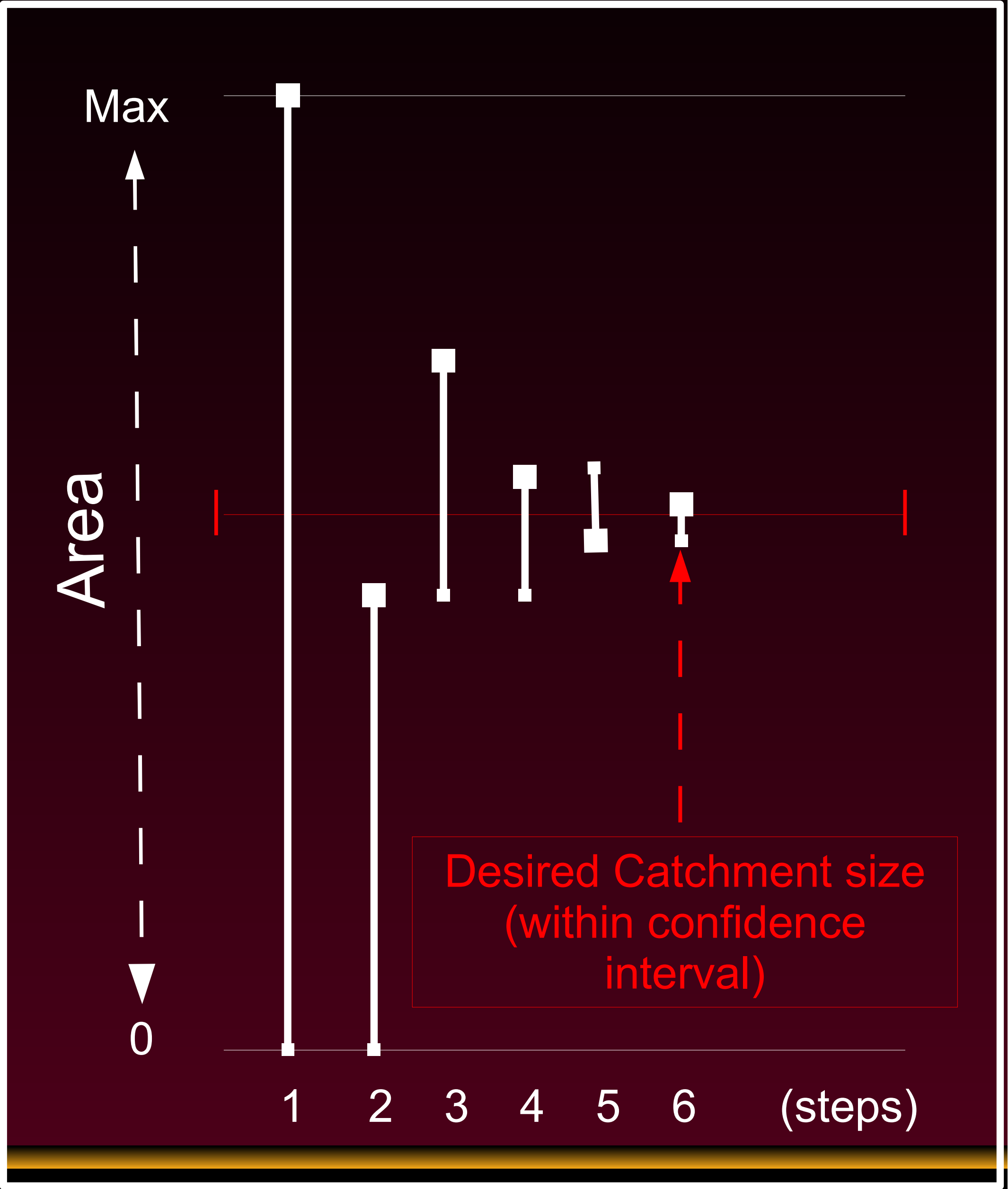
- **If:** Test Area < Desired Area

→ Lo Cutoff = (Hi Cutoff + Lo Cutoff)/2

→ Set Test Area Boundary to Min Cutoff

- **If:** Test Area = Desired Area (+/- Interval)

→ Create Catchment Map

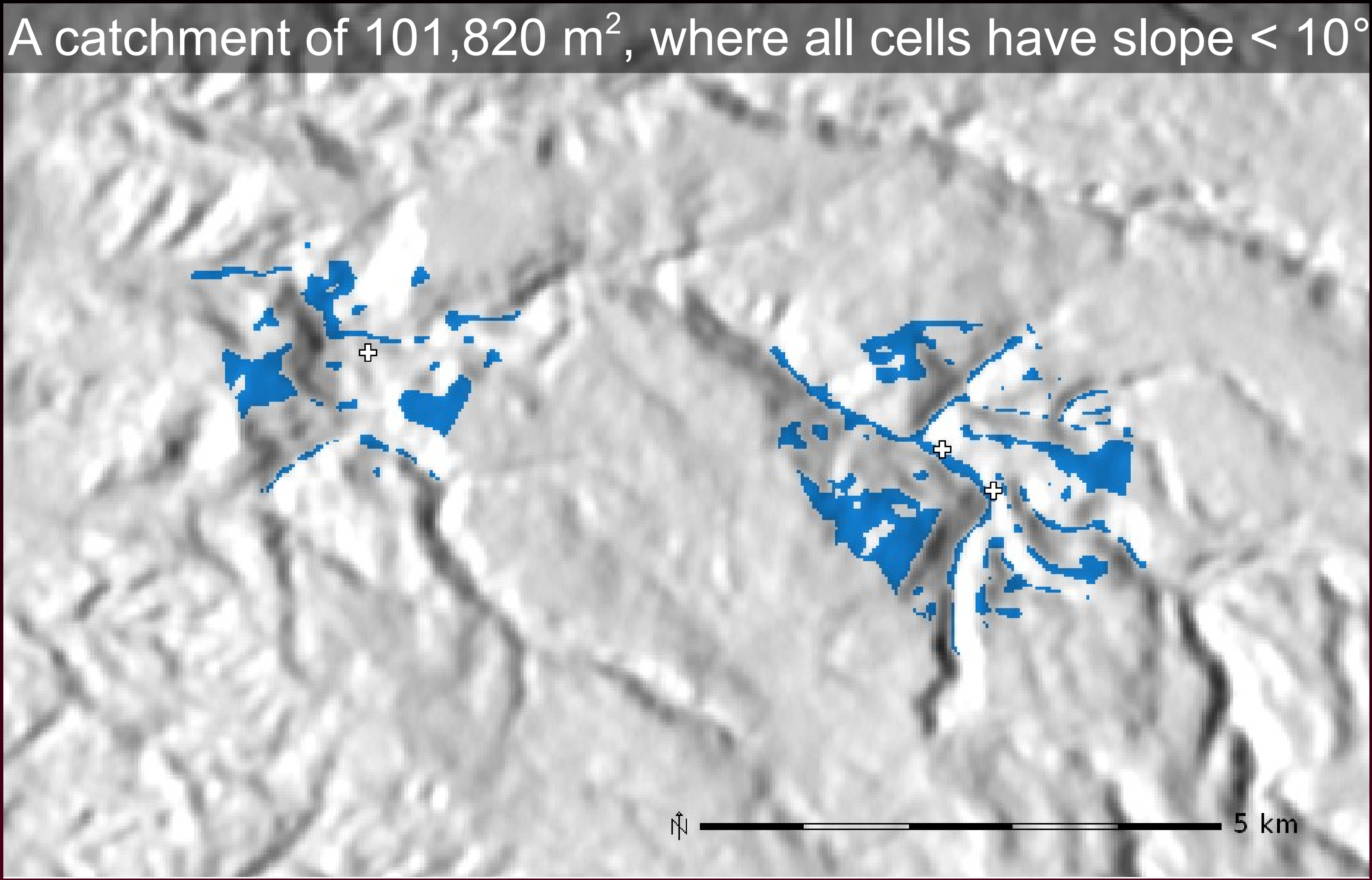


An Example of “r.catchment” Output

- Define a catchment of 100,000 m^2, with ±2% accuracy, and ignoring all cells where slope > 10°
- After 11 iterations, a catchment solution is reached.
- Catchment is 101,820 m^2, which is within 2% of the desired catchment size

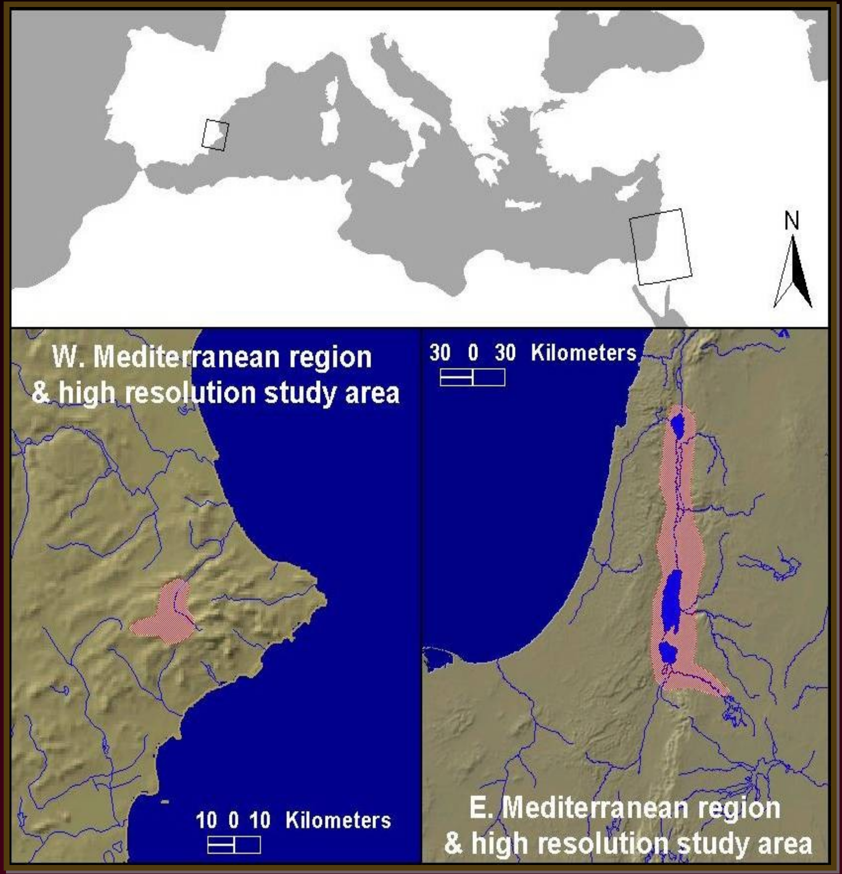
Step	Cost Distance Cutoff	Catchment Area
1	91933	80013450
2	45967	41070390
3	22983	11238870
4	11492	2814420
5	5746	651870
6	2873	64830
7	4309	257760
8	3591	136740
9	3232	93810
10	3412	112200
11	**3322**	**101820**

An Example of "r.catchment" Output

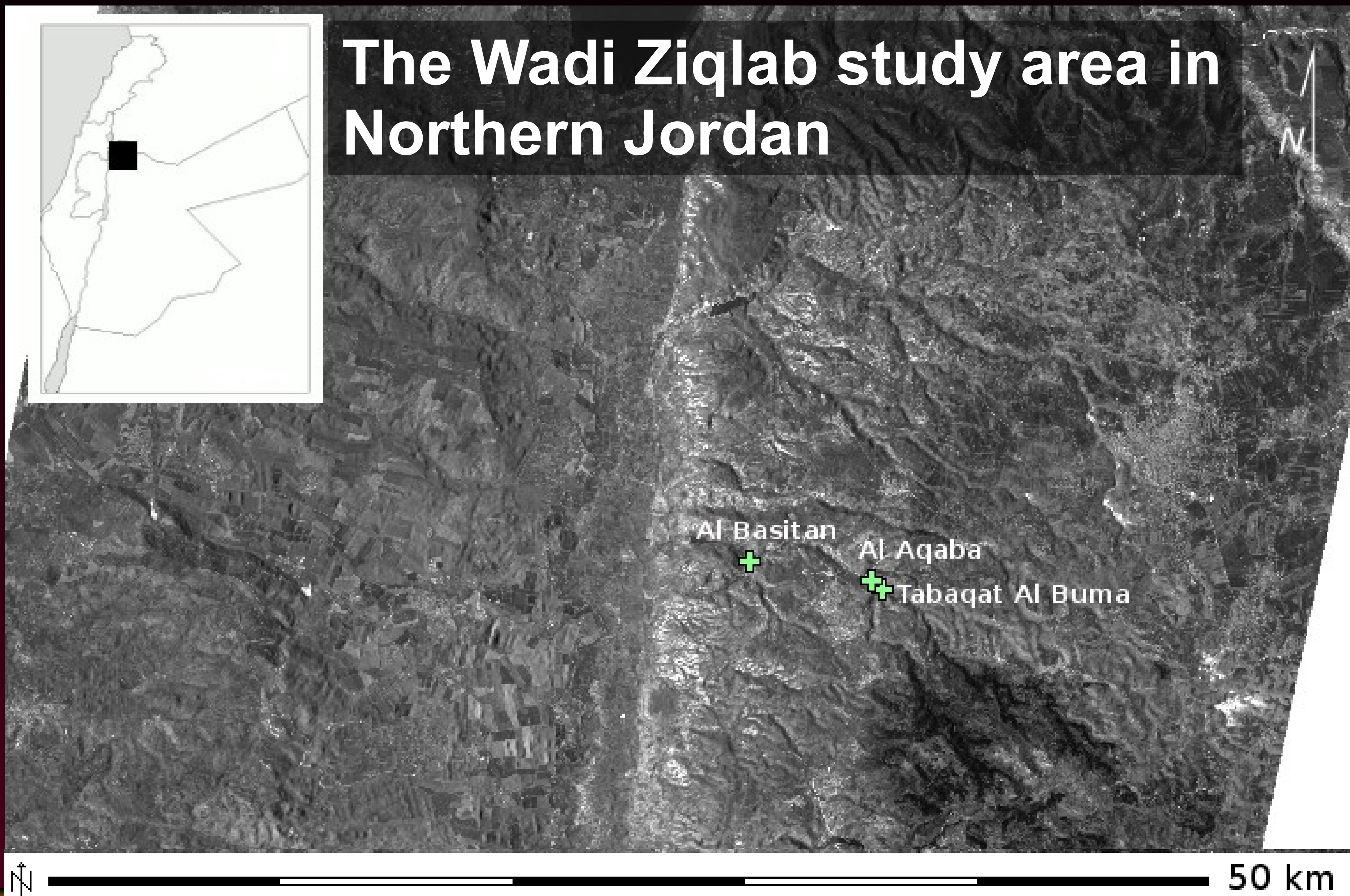


The MEDLAND Project

- The Mediterranean Landscapes Dynamics (MEDLAND) Project aims to assess the environmental impacts of early agropastoral societies in the Mediterranean region.
- Build a spatially-explicit computational modeling laboratory to conduct experiments
- Site catchment modeling with “r.catchment” is a core component of the modeling laboratory

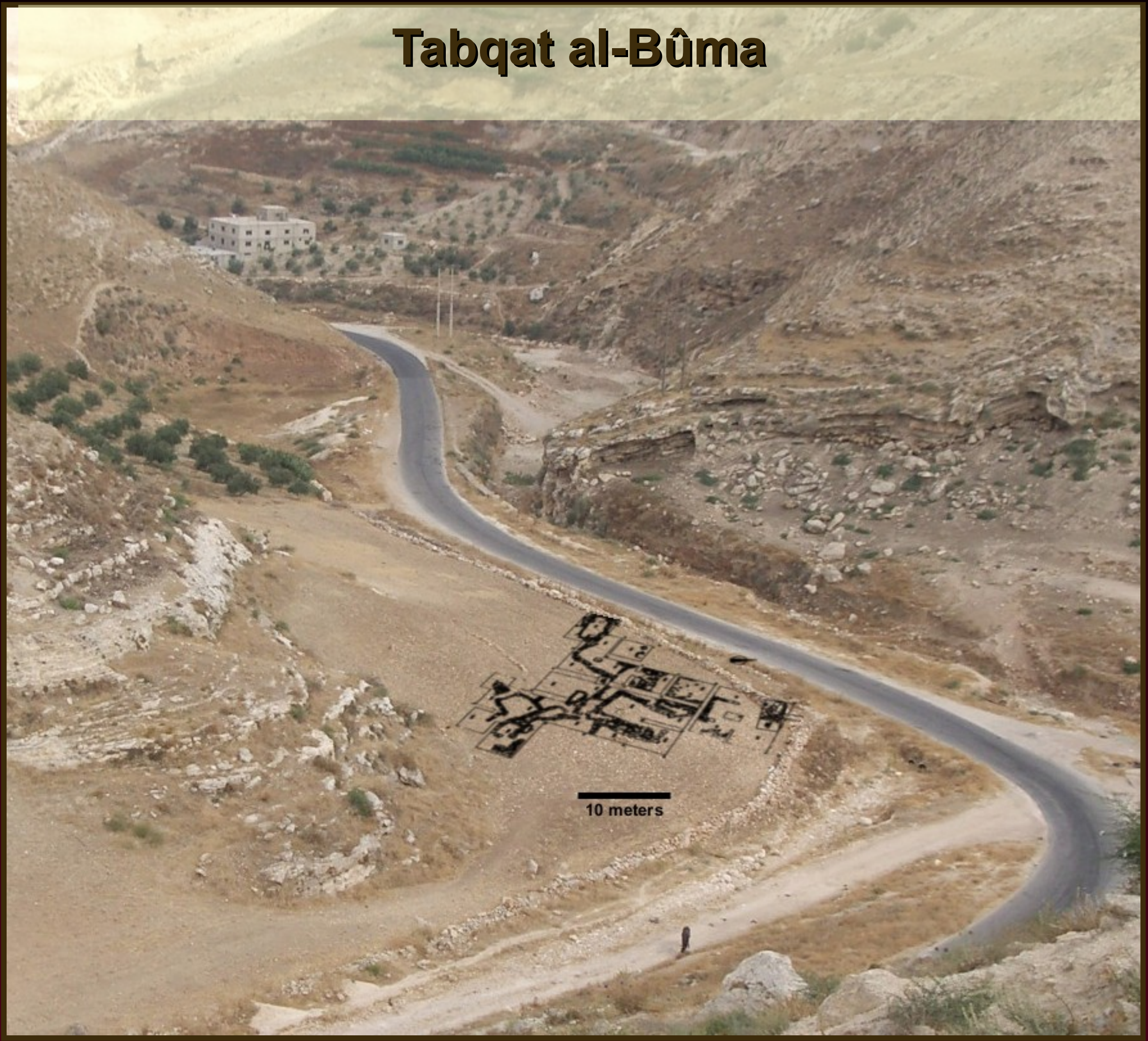


Case Study: Neolithic Pastoralism



Late Neolithic Sites

- Small agropastoral hamlets
- 1-3 households
- 6-18 people
- At least three sites dispersed through the region
- All roughly contemporaneous



Problem Statement

- Goat/sheep pastoralism was a significant component of the Late Neolthic subsistence economy
- However,the available archaeological evidence is fragmentary
- Thus, it is difficult to quantify the extent and exact character of Late Neolithic pastoralism

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- How to reconstruct the zone of Neolithic pastoral impacts?

Methods

- **Model Building**
  - Model Neolithic herd economy from modern ethnographic data.
  - Model Neolithic herd ecology from modern heritage breeds.
  - Model early Holocene climate patterns and use these to retrodict Neolithic vegetation patterns.
- **Experimentation**
  - Use techniques from rangeland science to calculate Neolithic herd sizes under various herding strategies (herd compositions and catchment sizes).
  - Translate those herd sizes into human population estimates.
- **Testing**
  - Compare the output human population estimate to external population estimates (ie. from architectural studies).

Modeling Neolithic Herd Economy

- **The importance of herding in subsistence economy**
  - Very Low → Very Small Catchment (3 km^2)
  - Low → Small Catchment (9 km^2)
  - Medium → Medium Catchment (20.25 km^2)
  - High → Large Catchment (113 km^2)
- **Species composition of herds**
  - Goat dominated → 2 goats per sheep
  - Sheep Dominated → 1 goat per 2 sheep
  - Equally Mixed → 1 goat per sheep
- **Human subsistence dependency on herding returns**
  - High → 30 animals per person
  - Low → 10 animals per person

Modeling Neolithic Herd Ecology

			Browse:Graze Ratio			Total Fodder kg/year		
Animal	**Body weight (kg)**	**Daily fodder (kg)**	**Browse Dominated Landscape**	**Graze Dominated Landscape**		**Browse Dominated Landscape**	**Graze Dominated Landscape**	**Equally Mixed Landscape**
Baladi goat	40	2.45	3:2	3:7	Browse	350.4	175.2	*262.8*
					Graze	233.6	408.8	*321.2*
					Total			***584.0***
Awassi sheep	70	1.6	1:1	2:8	Browse	447.1	178.9	*313.0*
					Graze	447.1	715.4	*581.3*
					Total			***894.3***

- ***Awassi*** **sheep and** ***Baladi*** **goats are the modern breeds most analogous to Neolithic breeds of sheep and goats.**

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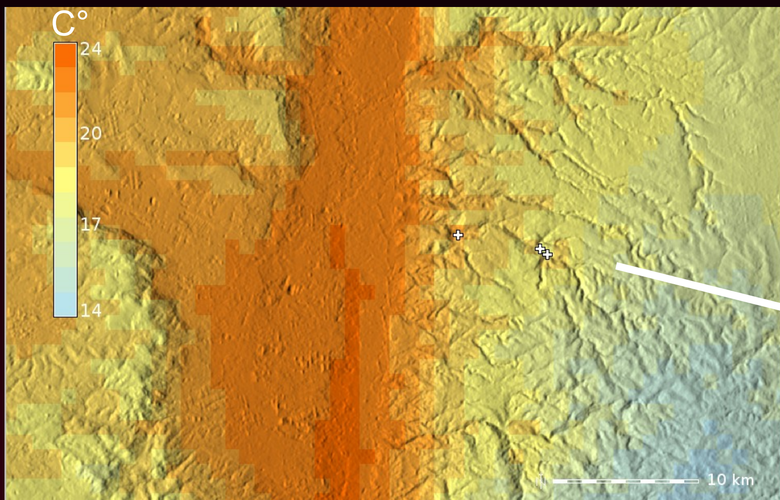
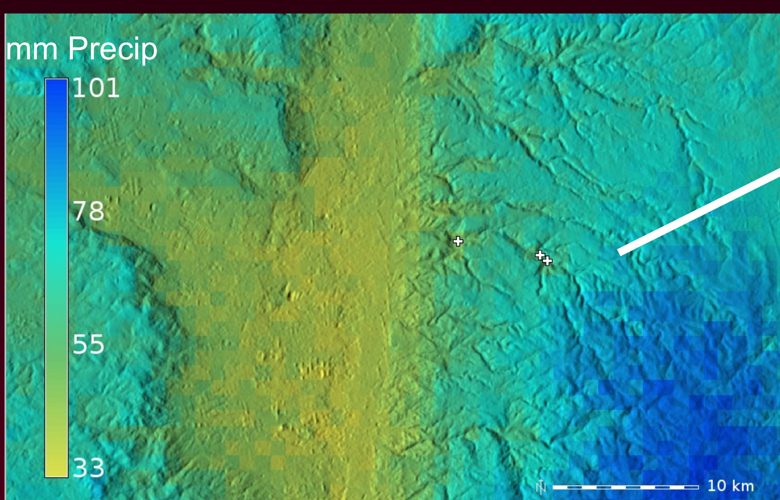
Modeling the Neolithic Environment

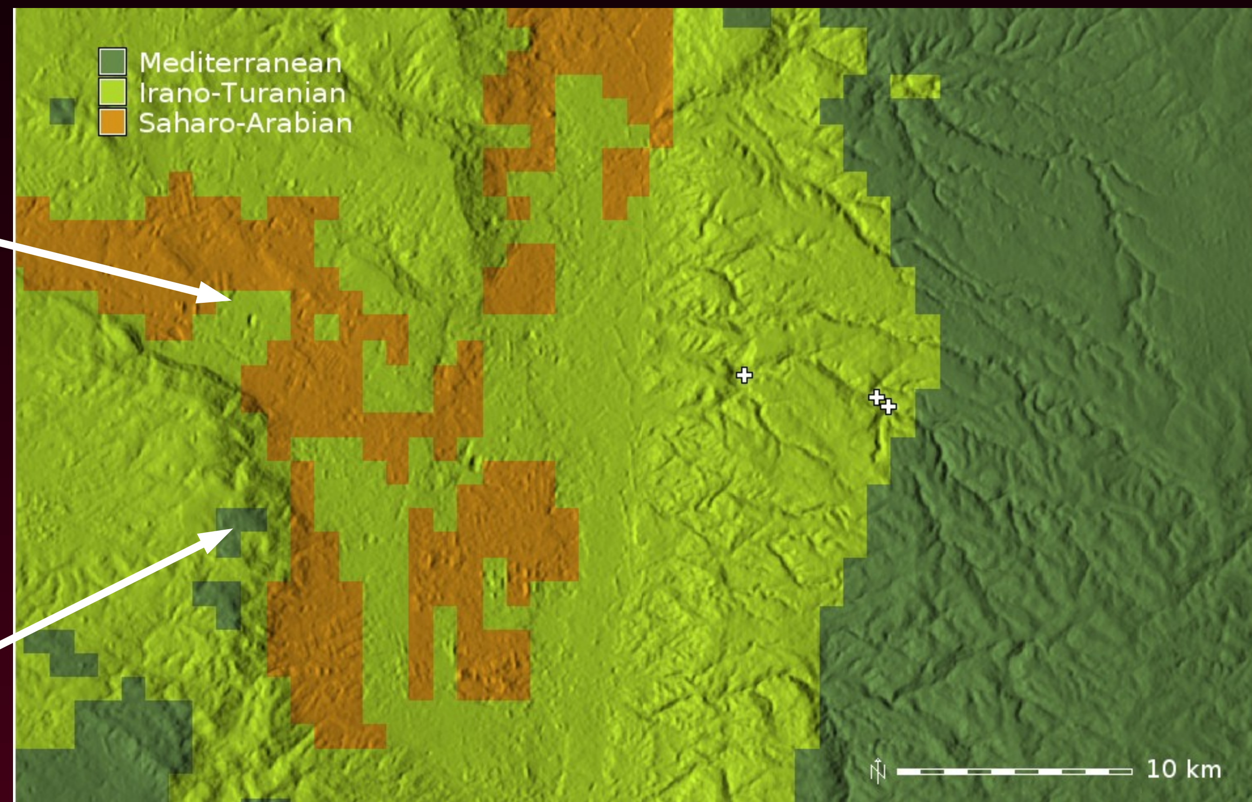
Archaeoclimatological Modeling



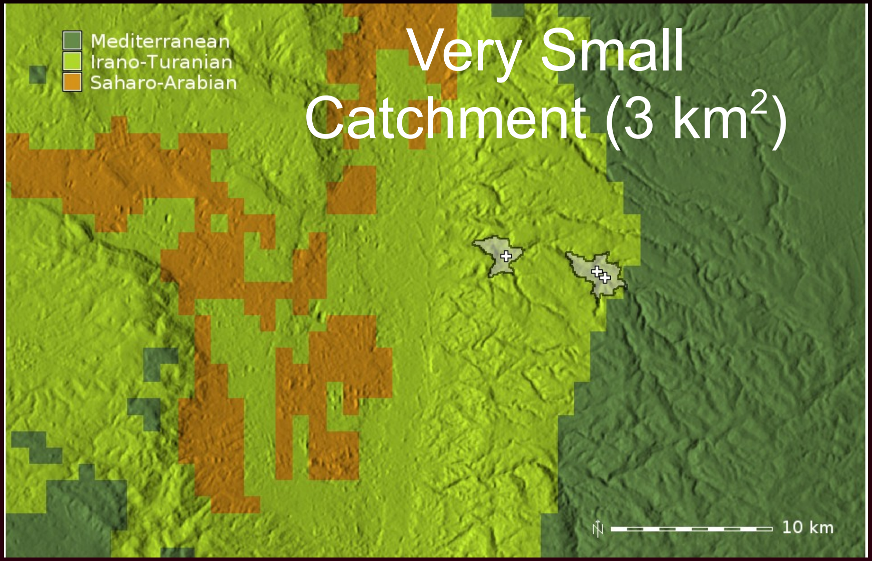


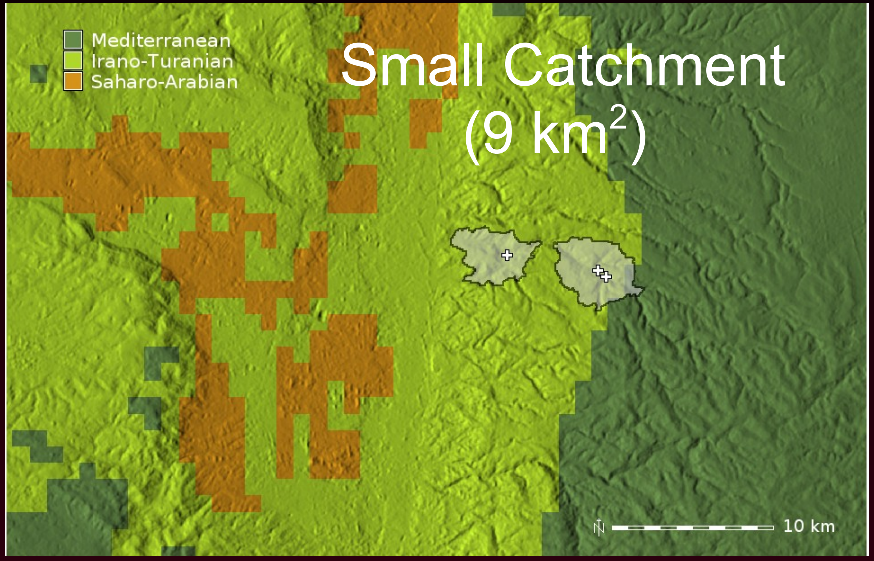
Maximum Entropy Vegetation Modeling

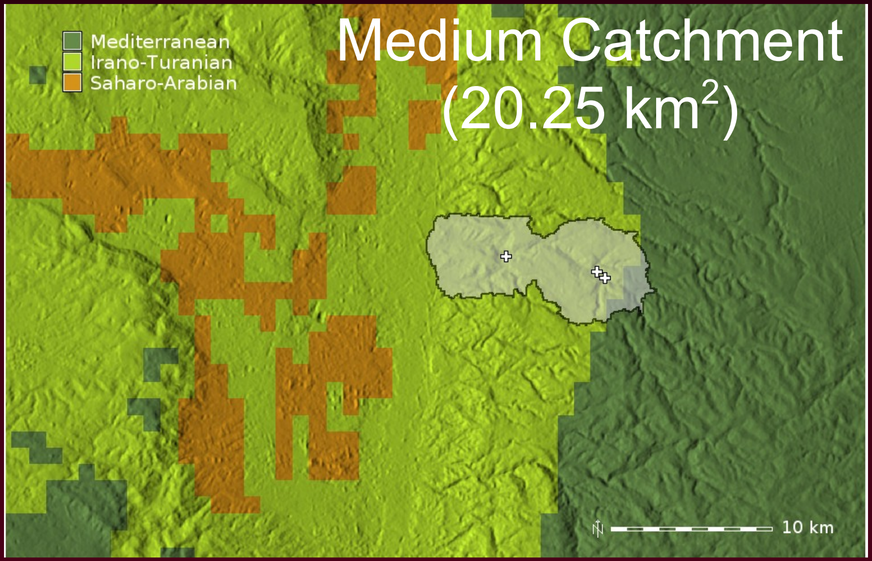
Estimates plant paleogeography from paleoclimate and topography

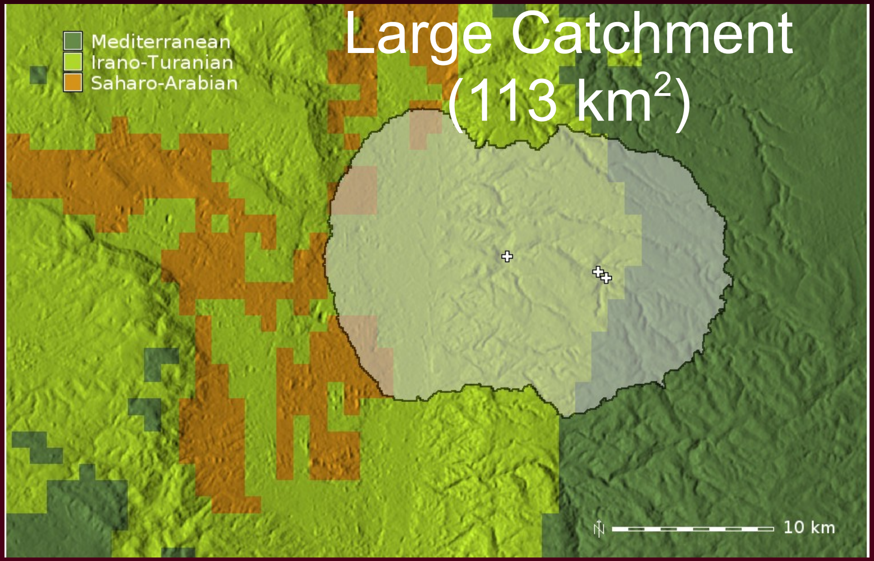


Modeling Pastoral Catchments









Results: Animal Populations

Average herd size per site					
Goat:Sheep Ratio	**Animal**	**Very Small Catchment (3 km^2)**	**Small Catchment (9 km^2)**	**Medium Catchment (20.25 km^2)**	**Large Catchment (113 km^2)**
2:1	Goats	13	38	87	425
	Sheep	6	19	43	213
	Total	*44*	*135*	*306*	*1503*
1:1	Goats	13	40	91	449
	Sheep	13	40	91	449
	Total	*62*	*188*	*427*	*2097*
1:2	Goats	5	17	38	185
	Sheep	11	33	75	370
	Total	*39*	*117*	*266*	*1307*

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Results: Human Populations

Predicted maximum population per site				
Goat:Sheep Ratio	Very Small Catchment ($3\ km^2$)	Small Catchment ($9\ km^2$)	Medium Catchment ($20.25\ km^2$)	Large Catchment ($113\ km^2$)
2:1	1 – 4 people	4 – 13 people	10 – 31 people	50 – 150 people
1:1	2 – 6 people	6 – 19 people	14 – 43 people	70 – 210 people
1:2	1 – 4 people	4 – 12 people	9 – 27 people	44 – 131 people

- **Compare to external population estimate of 6-18 ppl/site.**
- **Best match are the Small to Medium Catchments.**
- **Late Neolithic Pastoralism was most probably small to medium scale, and most probably affected an area between 9 and $20km^2$ around the Late Neolithic sites.**

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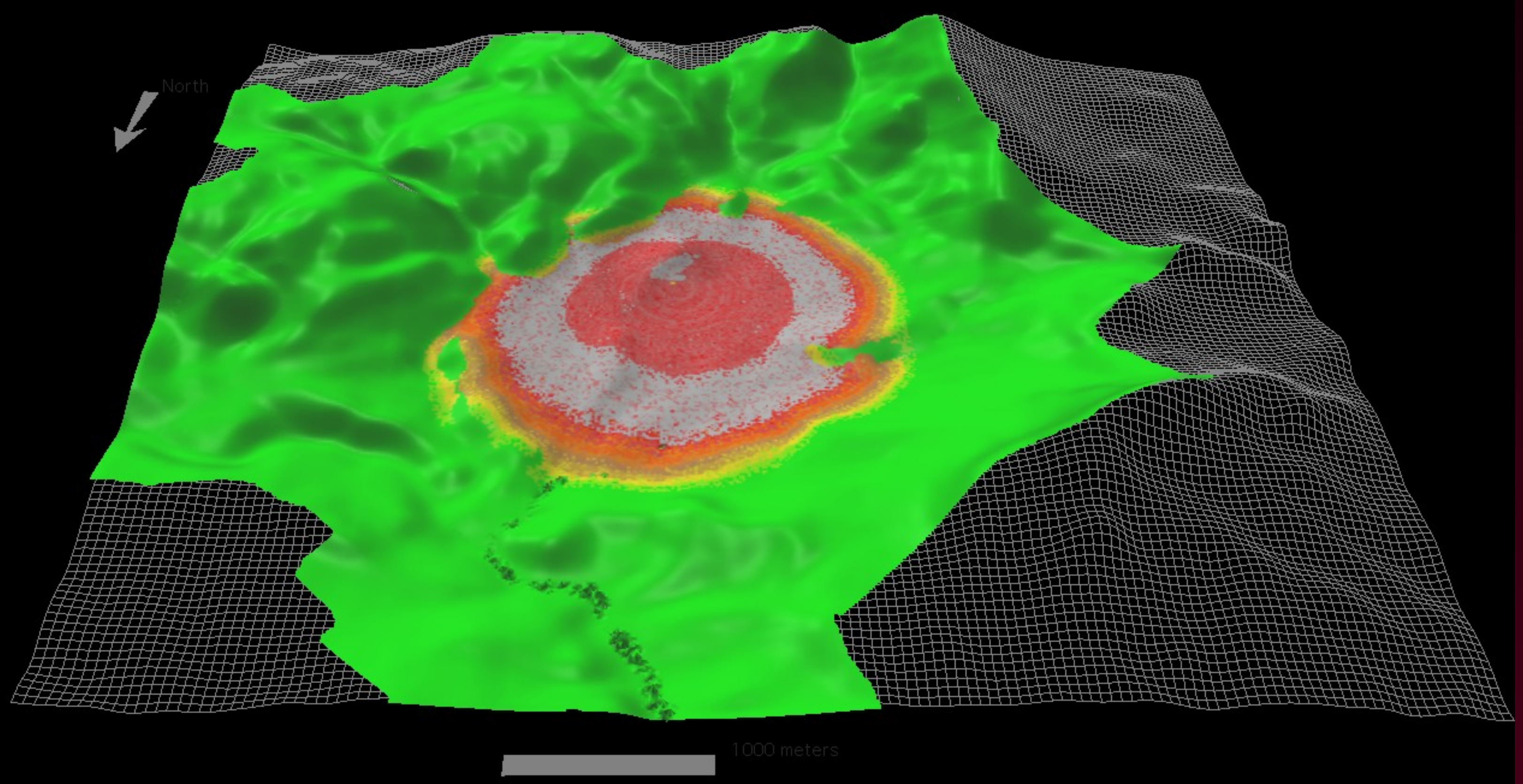
Conclusions

- A refined understanding of how to do catchment modeling leads to a better integration with modern GIS tools ("r.catchment") facilitating the inclusion of additional socioecologial variables to produce more complex—and thus more realistic—catchment models.
- Approaching the reconstruction of ancient catchments as a series of simulation experiments allows for a clearer and more robust understanding of ancient human/environment interaction than can be gleaned from the archaeological record alone.

The next step: Dynamic Catchment Evolution

Coupled GIS-ABM: AP-Sim




The End!
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