Simulating the long-term effects of agropastoral landuse decisions:

A computational modeling approach to the Prepottery/Pottery Neolithic transition in northern Jordan

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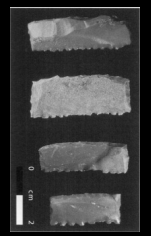
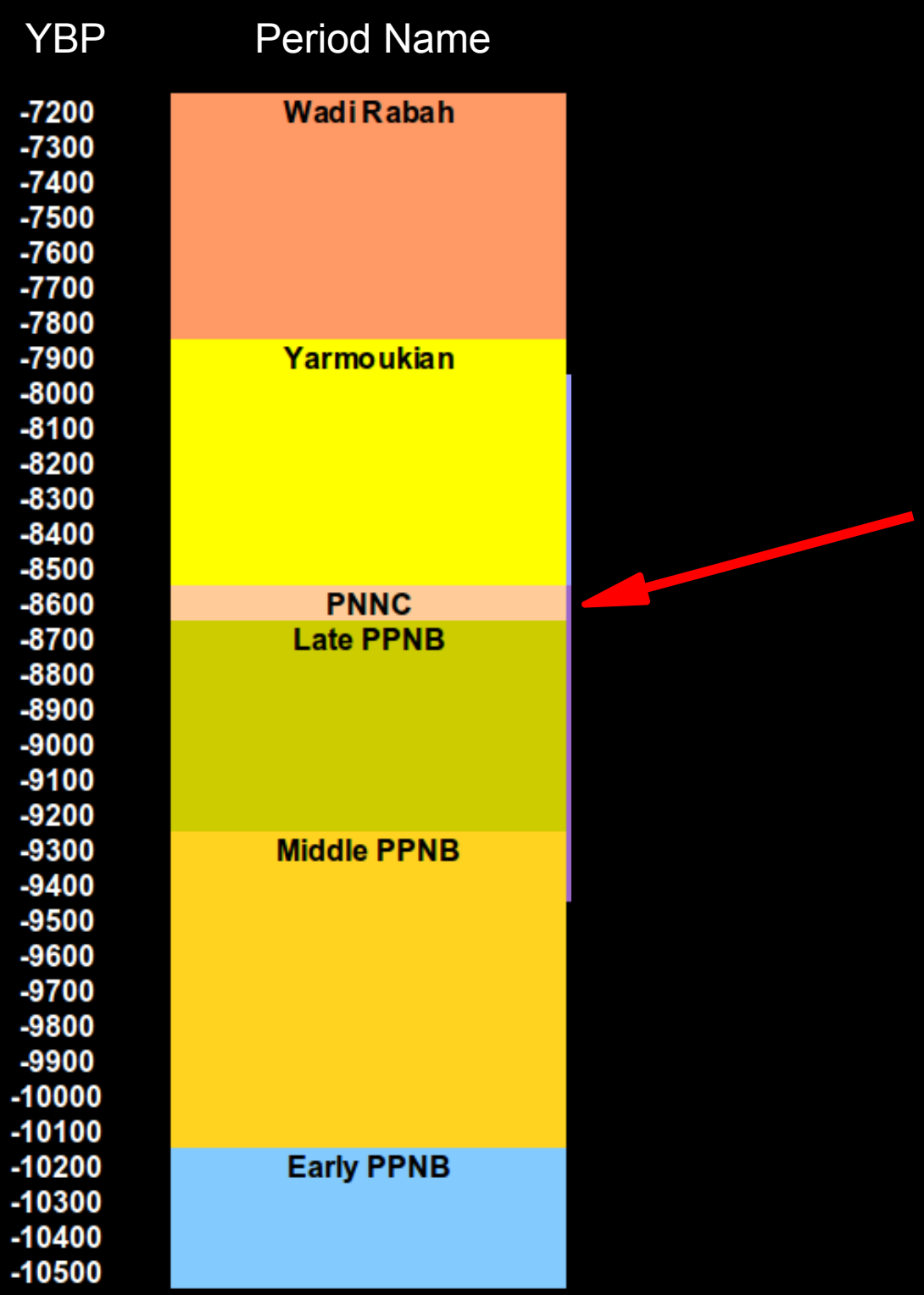
Problem Domain

The Prepottery/Pottery Neolithic Transition in the Southern Levant

- Late PPNB/C (*c.* 9250 – 8500 B.P.)
  - High levels of settlement centralization, with dense habitation in a few large agglomerated towns, each containing up to3000 people
  - Highly standardized blade-based stone tool technology, advanced knowledge of plaster-making, multistory dwellings with many rooms, large statuary, and spectacular art



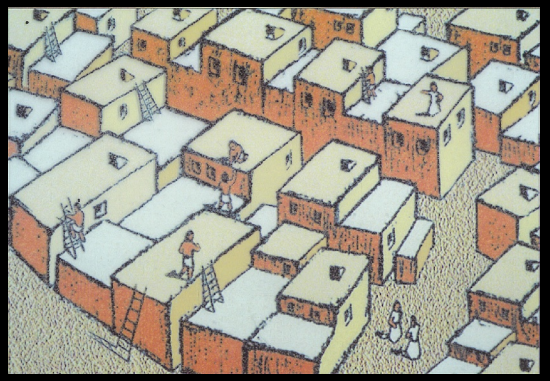
- Late Neolithic (c. 8500 – 7000 B.P.)
  - Generally much less spectacular than the PPNB/C
  - Widely dispersed in small hamlets of only about 20 people each, with fewer larger settlements of a few hundred people
  - Stone tools made from non-standardized flakes, very little art, simple one-room houses, pottery invented, but most pots undecorated coarse-wares


YBP
Period Name
-7200
-7300
-7400
-7500
-7600
-7700
-7800
-7900
-8000
-8100
-8200
-8300
-8400
-8500
-8600
-8700
-8800
-8900
-9000
-9100
-9200
-9300
-9400
-9500
-9600
-9700
-9800
-9900
-10000
-10100
-10200
-10300
-10400
-10500
Wadi Rabah
Yarmoukian
PNNC
Late PPNB
Middle PPNB
Early PPNB

Potential Motivators for PPN/LN Transition

1) Human-Caused Environmental Degradation

- Depletion of soil fertility due to intensive farming, increased erosion due to overgrazing and woodgathering for plaster-making
- Perhaps in conjunction with climate change



2) Increased Social Stress of Life in the First Large Villages

- Larger populations, you don't really know everyone, increased occurrence of social friction, few social institutions exist to deal with these stresses
- Perhaps also in conjunction with environmental degradation, but emphasis on social motivators

3) Conscious Reformulation of Subsistence Behavior to Mitigate Risk

- Dispersal spreads risk over many ecotones, spreads access to resources, increases chances of success
- No specific social or environmental motivators required, but these could be factors

Project Area and Background

Neolithic Sites in Wadi Ziqlab

N

WT4 - Tayiba Site

WZ120 - Tell Rakkan

WZ135 - Al Basitan

WZ300 - Al Aqaba

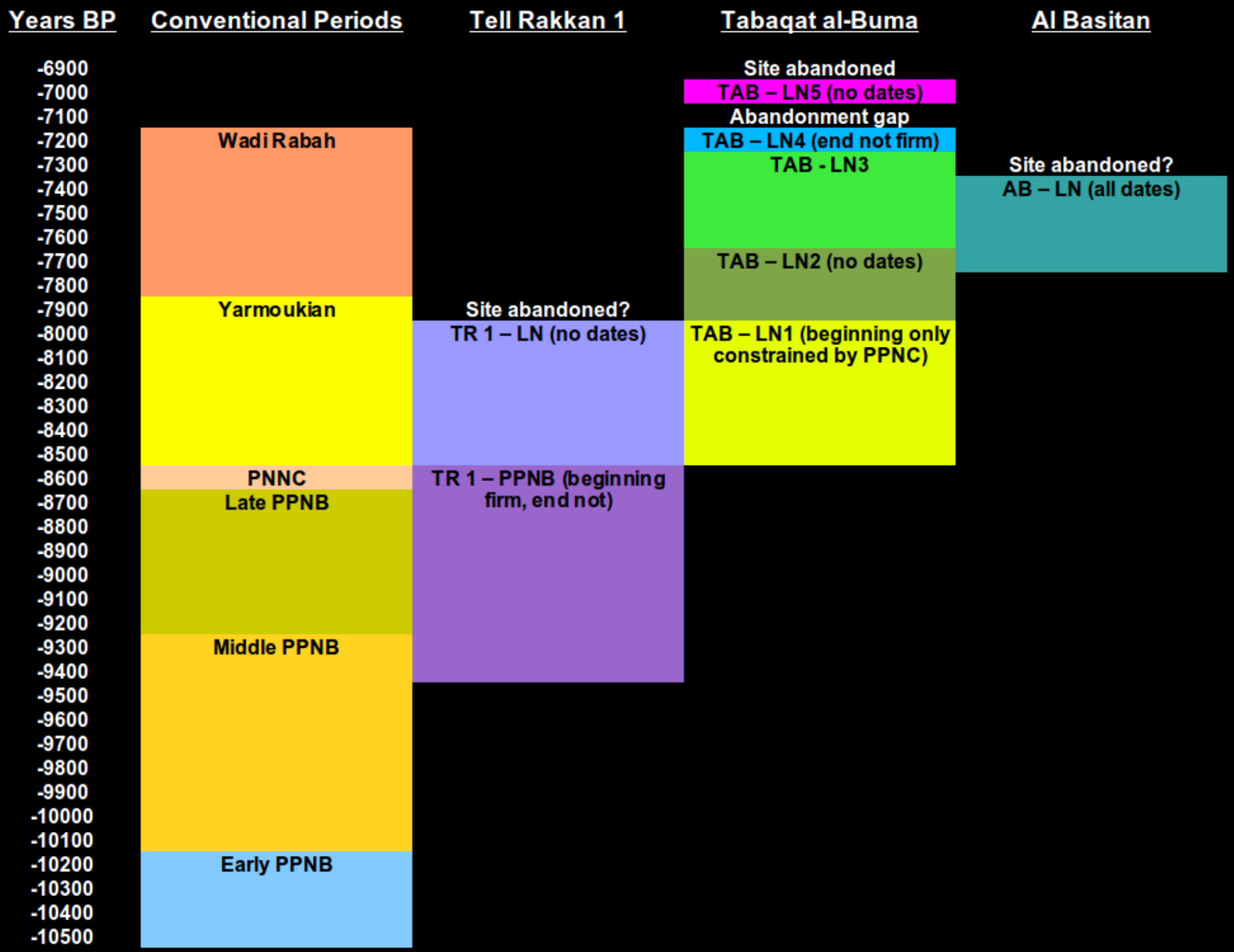
WZ200 - Tabaqat al Buma

WZ121 - Tubna

-200
0
200
400
600
800
1000

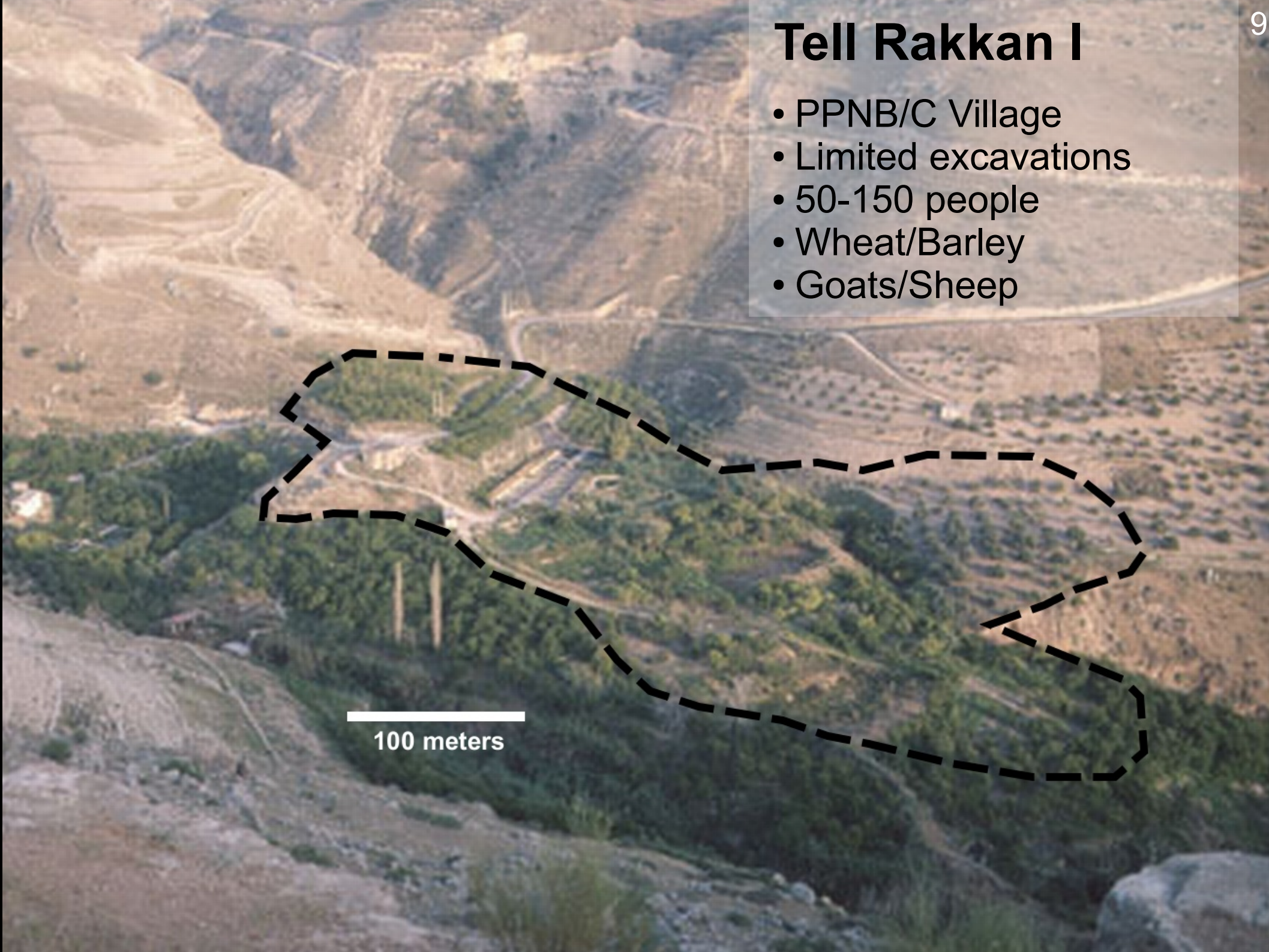
10 km

Timeline of the Neolithic in Wadi Ziqlab



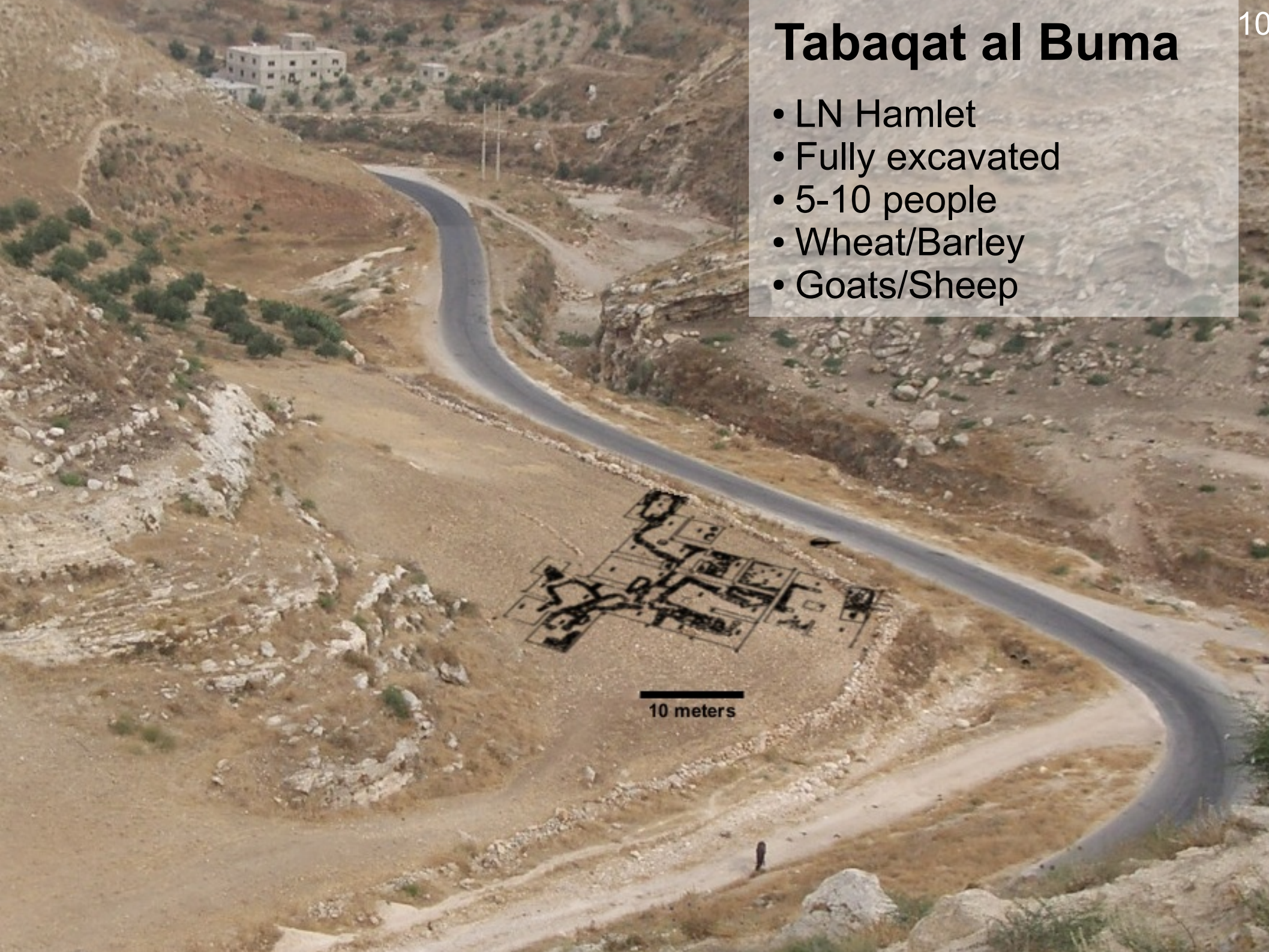
Tell Rakkan I

- PPNB/C Village
- Limited excavations
- 50-150 people
- Wheat/Barley
- Goats/Sheep



Tabaqat al Buma

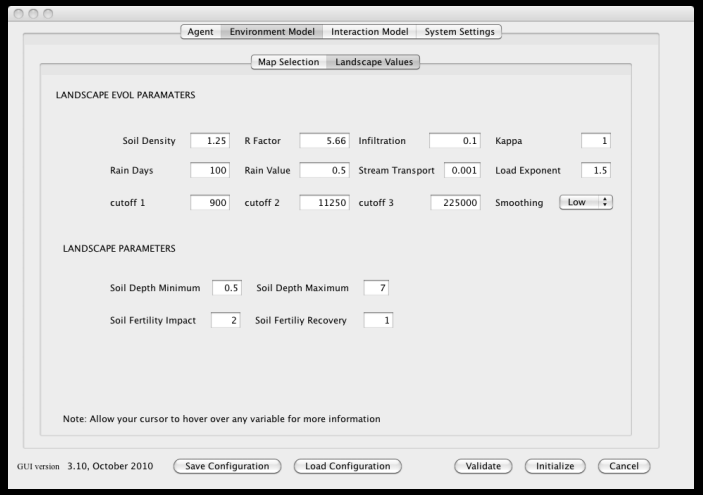
- LN Hamlet
- Fully excavated
- 5-10 people
- Wheat/Barley
- Goats/Sheep

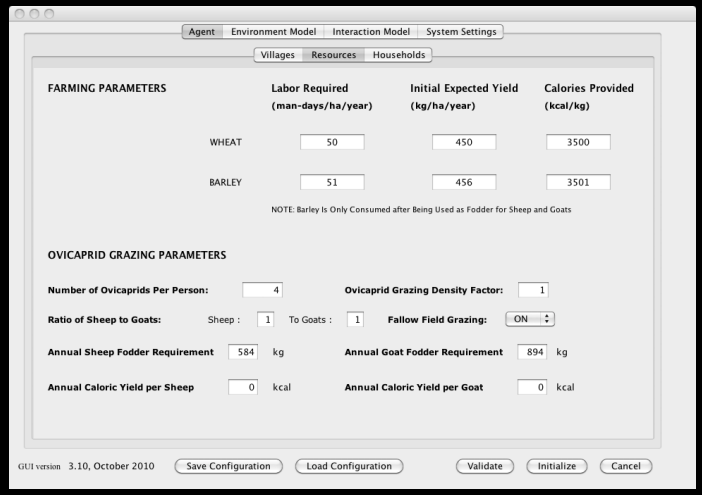


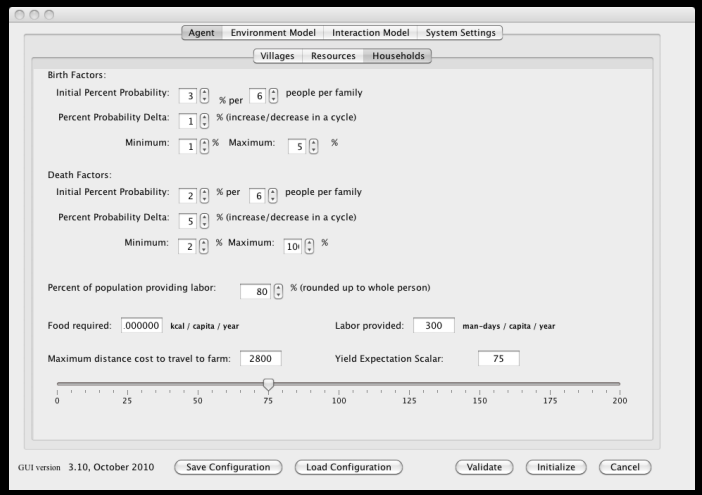
Simulation Experiment Protocol

Basic Research Design

- Simulate agropastoral landuse around Tell Rakkan I for the 700 year period of the PPNB/C
- Several models, parameterized to represent potential Neolithic agropastoral subsistence systems.
- Systematically vary a small number of the most important components of potential agropastoral subsistence systems between models
- Keep all other variables static between models
- Models to serve as “Hypothesis Generators” with which to reexamine the archaeological record







Modeling 6 Potential Neolithic Subsistence Systems

	1) Good Pastoralists	2) Good Agropastoralists	3) Good Agriculturalists
Agropastoral ratio:	20/80	50/50	80/20
Ovicaprids per person:	26	17	7
Herd stocking rate:	~0.15 animals/ha	~0.15 animals/ha	~0.15 animals/ha
Farming fertility decline:	1.00%	1.00%	1.00%

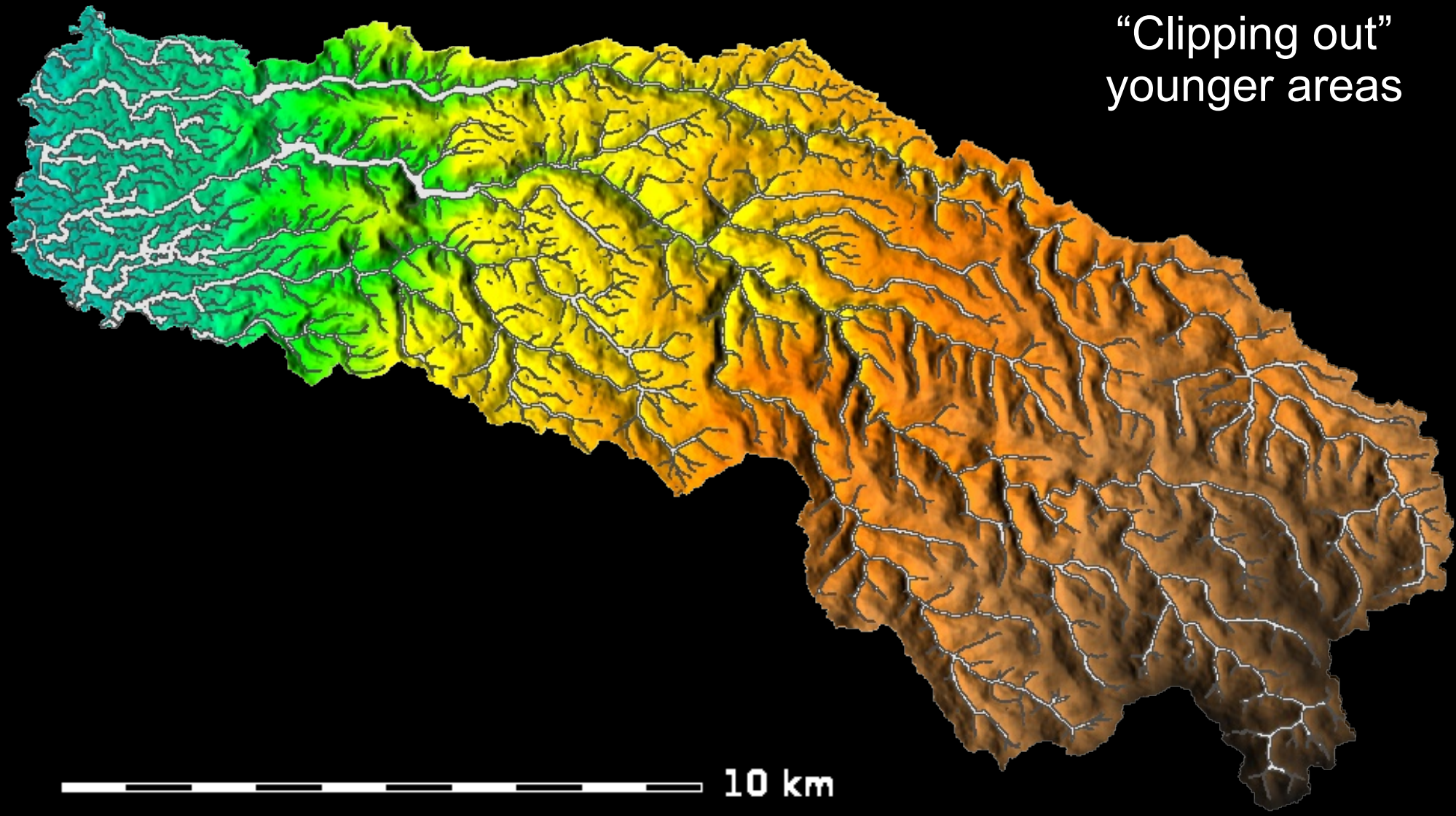
	4) Greedy Pastoralists	5) Greedy Agropastoralists	6) Greedy Agriculturalists
Agropastoral ratio:	20/80	50/50	80/20
Ovicaprids per person:	26	17	7
Herd stocking rate:	~0.3 animals/ha	~0.3 animals/ha	~0.3 animals/ha
Farming fertility decline:	2.00%	2.00%	2.00%

Agropastoral Economic Data

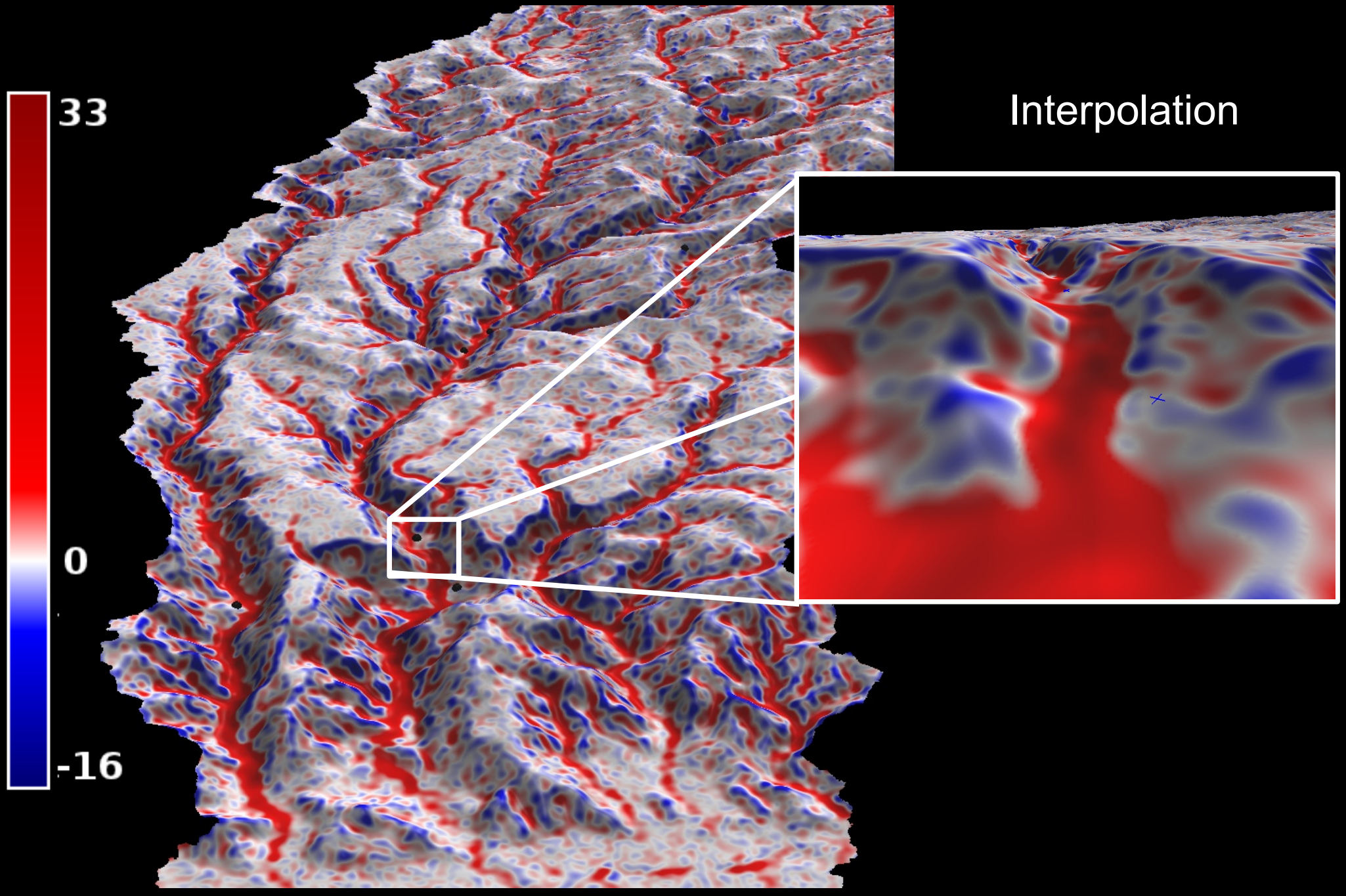
Data type	Data		Source
Pastoral product yields	*Baladi Goat*	*Awassi Sheep*	
Milk output (kg/yr):	200	60	Degen 2007
Milk energy (kcal/kg):	753.6	1005.6	Mavrogenis 1988
Percent not suckled:	66%	66%	Nablusi 1993, Epstien 1982
Percent milch animals:	36%	20%	Nyerges 1980
Milk yields (kcal/yr):	**99475.2**	**39821.76**	
Meat output (kg/animal):	10.09	14.88	Sen 2004
Meat energy (kcal/kg):	1090	2300	USDA 2011
Percent meat animals:	25%	25%	Nyerges 1980
Meat yields (kcal/yr):	**10998.1**	**34224**	
Goat:Sheep Ratio:	**2**	**1**	Ullah 2011
Average yield per head in herd (kcal/yr):	**38560.597**	**16520.352**	
Ecological characteristics of herd animals	*Baladi Goat*	*Awassi Sheep*	
Body weight (kg):	40	70	Wilson 1982, Epstien 1982, Degen 2007
Fodder requirement (kg/yr/head):	584	894.25	Stuth and Sheffield 1991
Percent diet from barley fodder:	10%	10%	Thompson 1982
Wild fodder need (kg/yr/head):	**525.6**	**804.825**	
Barley need (kg/yr/head):	**42.05**	**71.54**	
Agricultural Product Yields	*Barley*	*Wheat*	
Energy yield (kcal/kg):	3000	3540	Smith 2006, Fairbairn 1999
Maximum yields 7 (kg/ha):	2500	3500	Pswarayi et al 2008, Araus et al. 1998, 2001
Wood gathering			
Wood need (kg/person):	**2000**		Karanth 2006
Gathering intensity (kg/m^2):	**0.08**		Karanth 2006

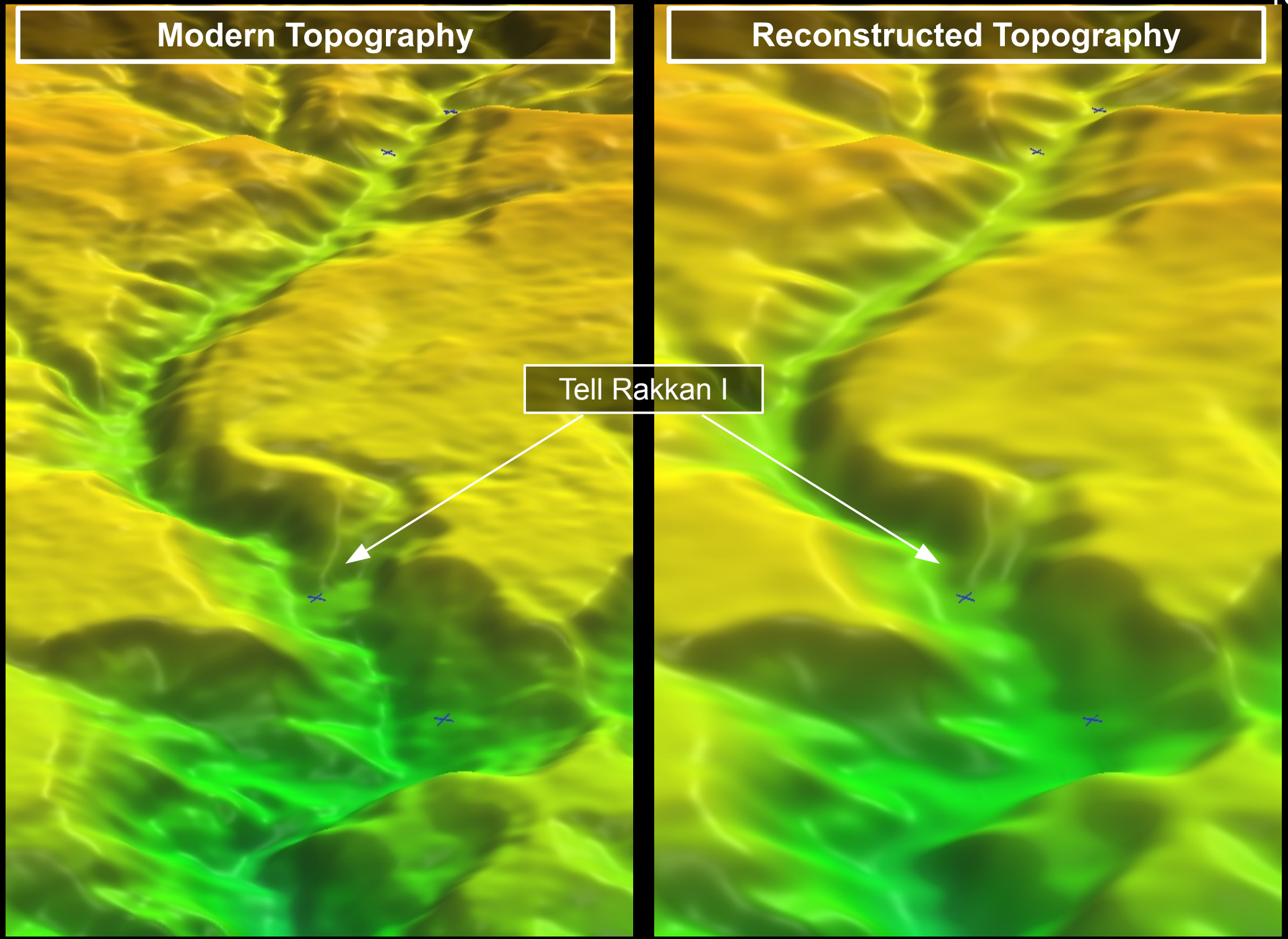
Paleoenvironmental Reconstruction

Reconstructing Neolithic Topography

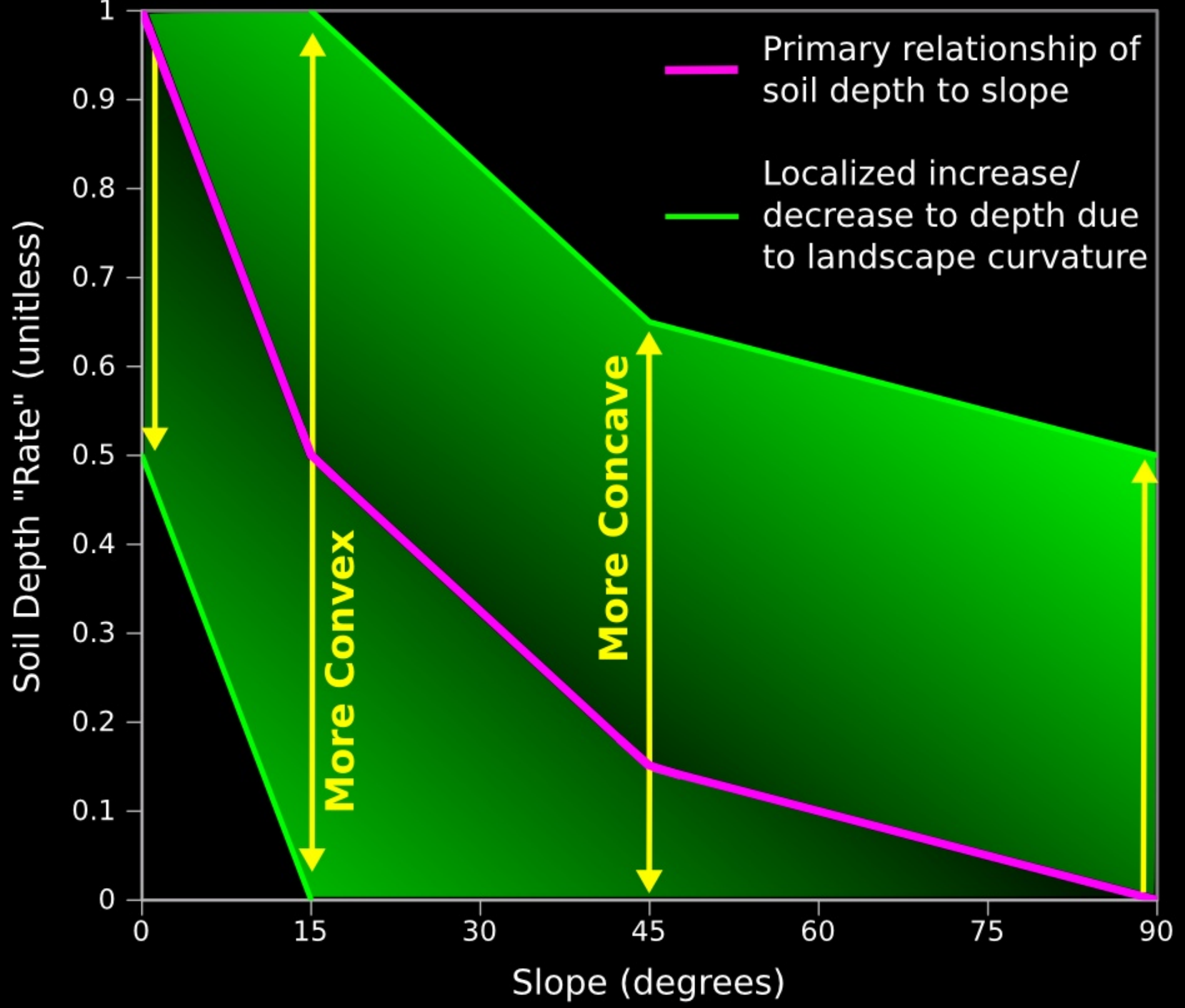


Reconstructing Neolithic Topography

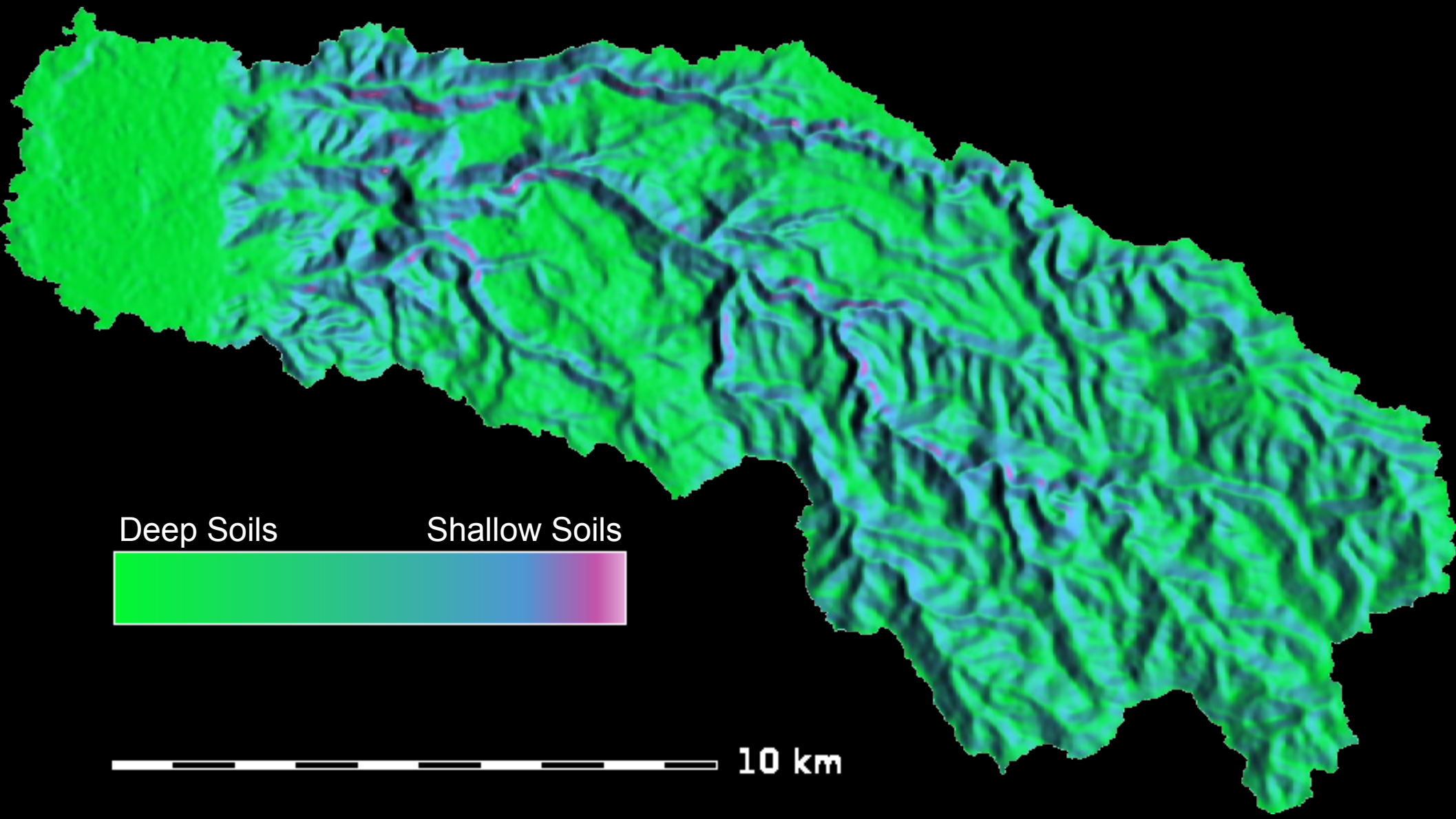



Modern Topography
Reconstructed Topography
Tell Rakkan I

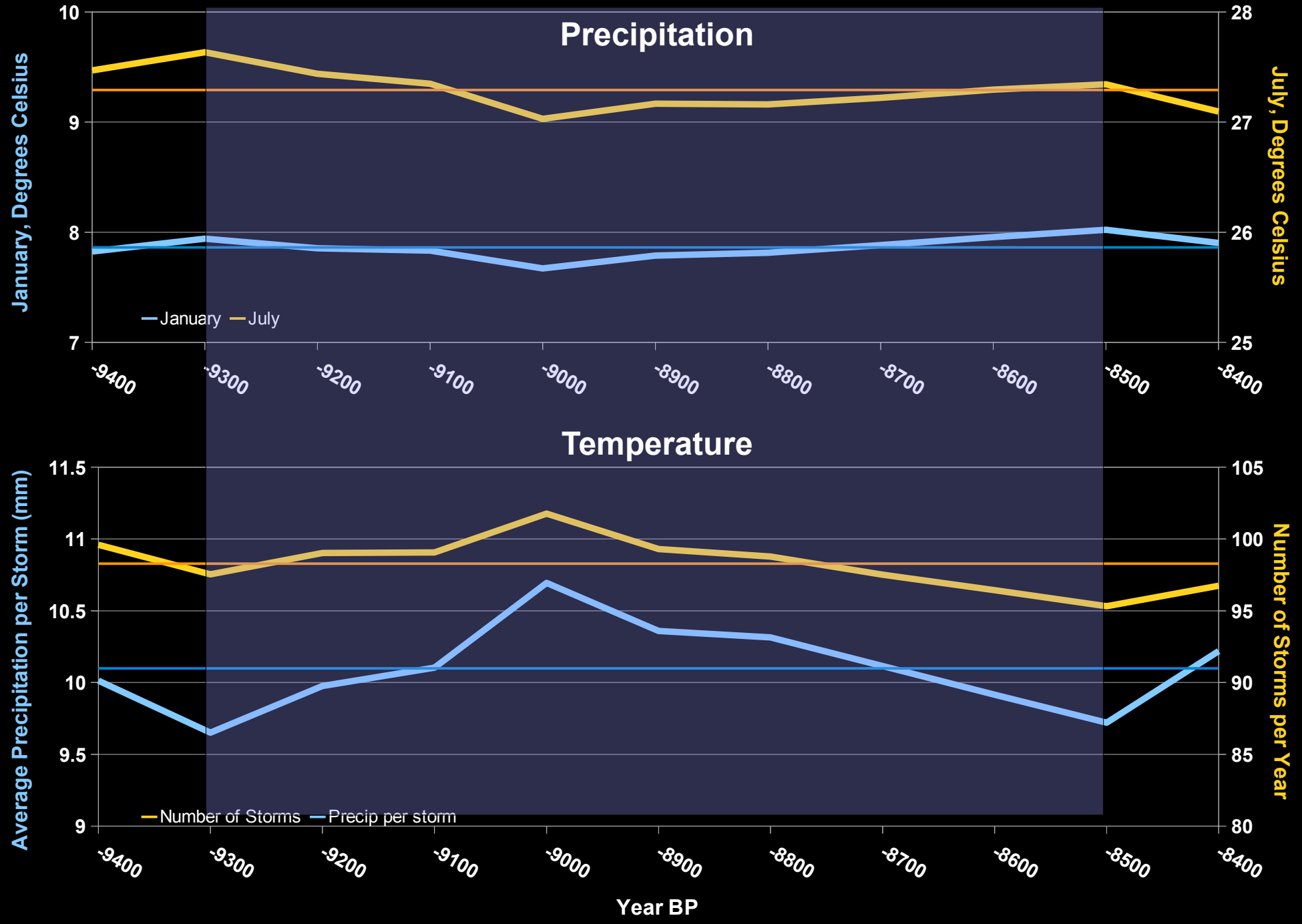
Estimating Soil Depth From Topography



Reconstructed Soil Depths

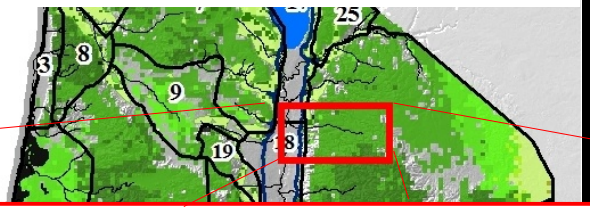


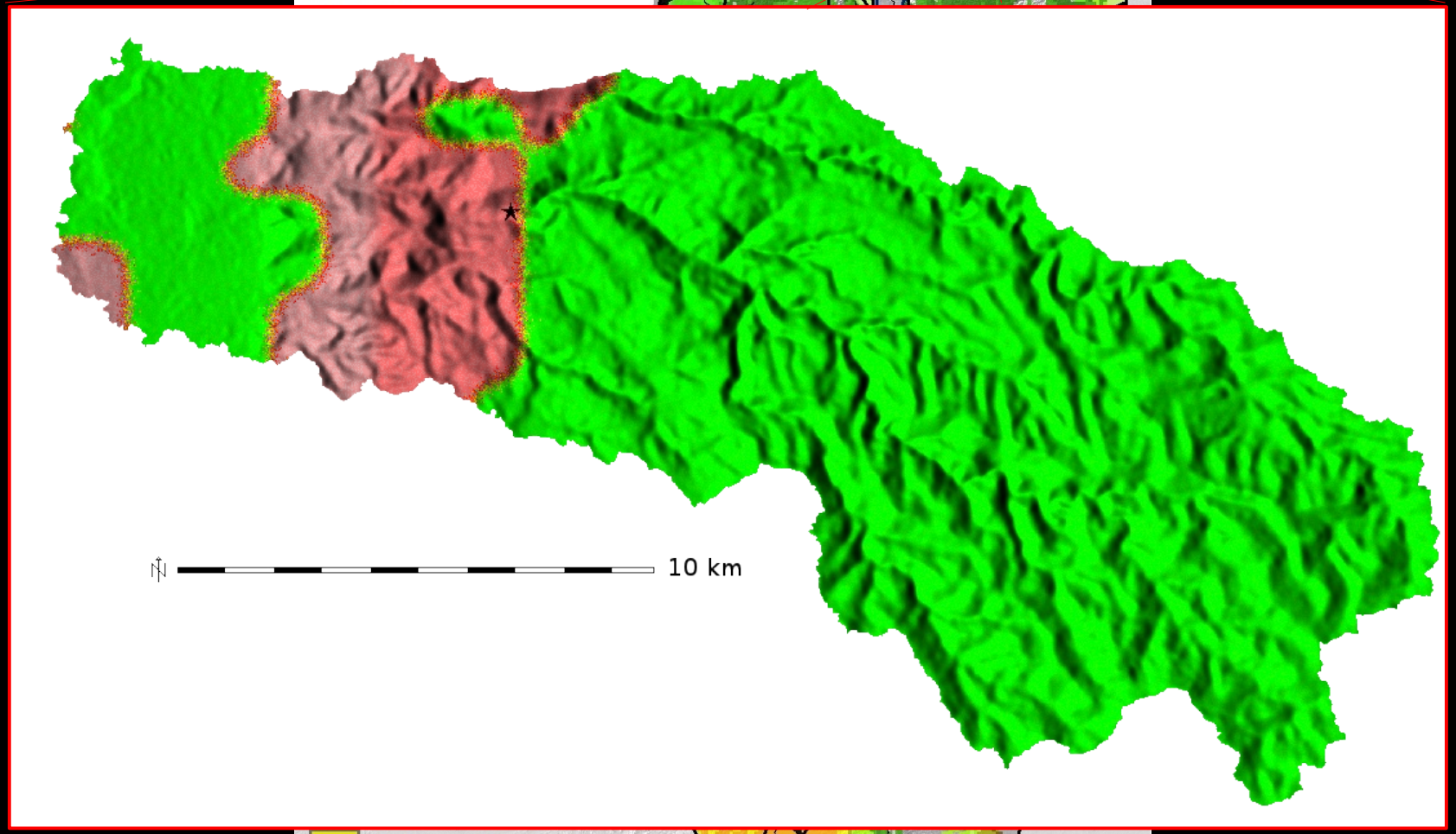
Reconstructing Neolithic Climate



Climax vegetation – PPNB/C period

1. Coastal Galilee
2. Akko Plain
3. Coastal Carmel
4. Sharon
5. Pleshet
6. Upper Galilee
7. Lower Galilee
8. Mt. Carmel





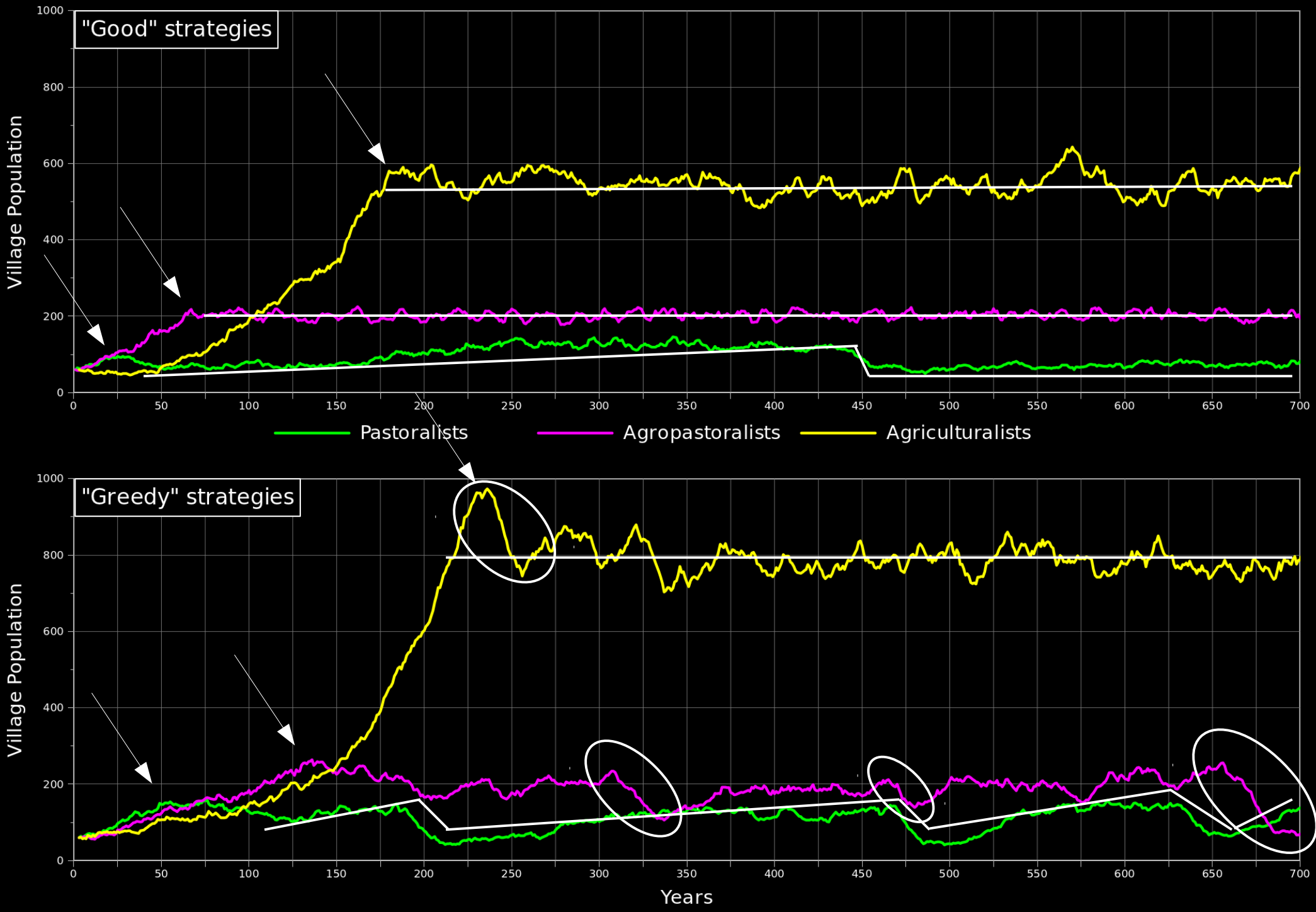
Mixed forest (Pine, Deciduous oak, Evergreen oak)

Pine forest

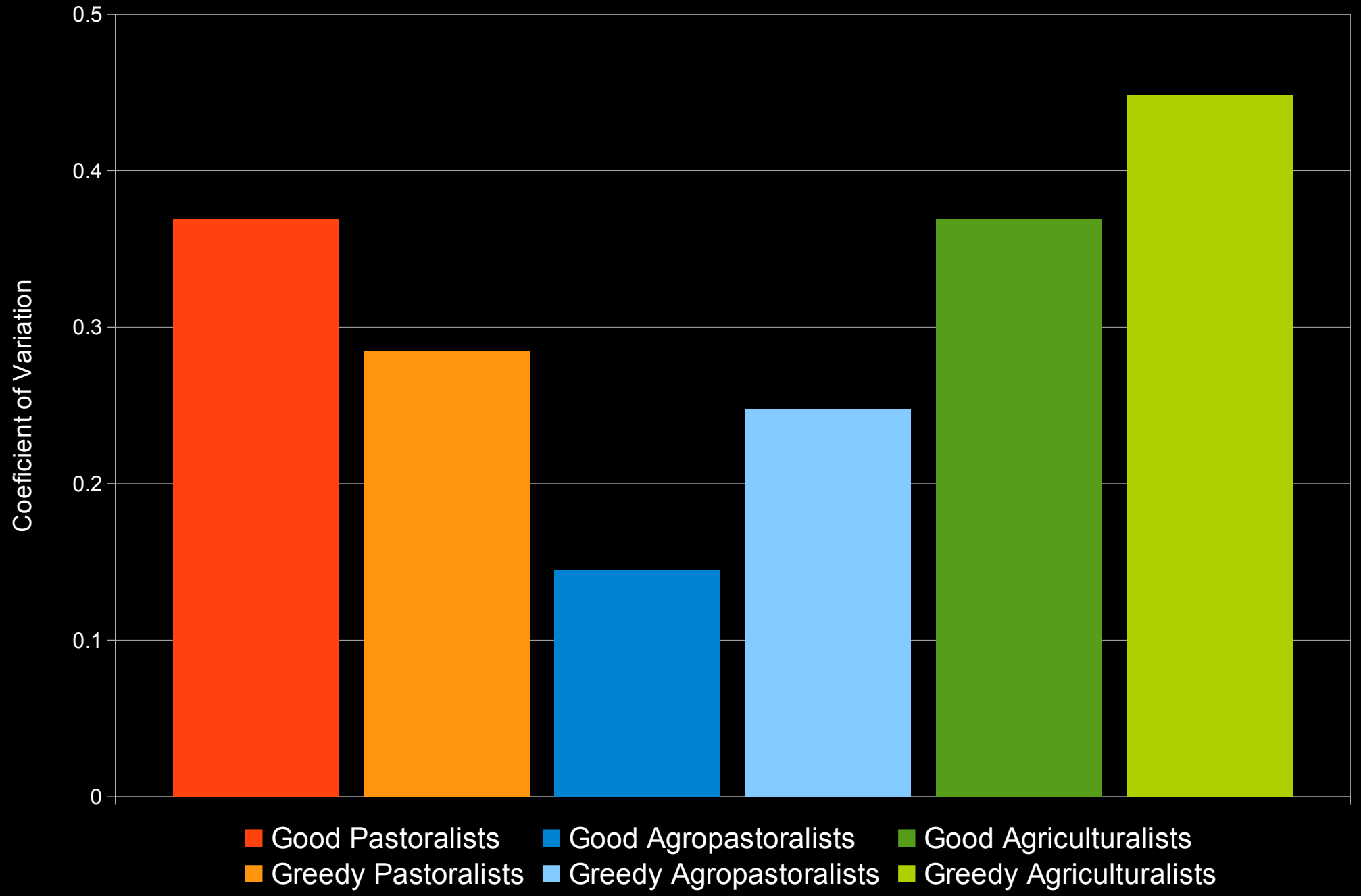
0 5 10 20 Mi

Results

Population Over Time



Variation in population over 700 years



Variation in population after first population peak

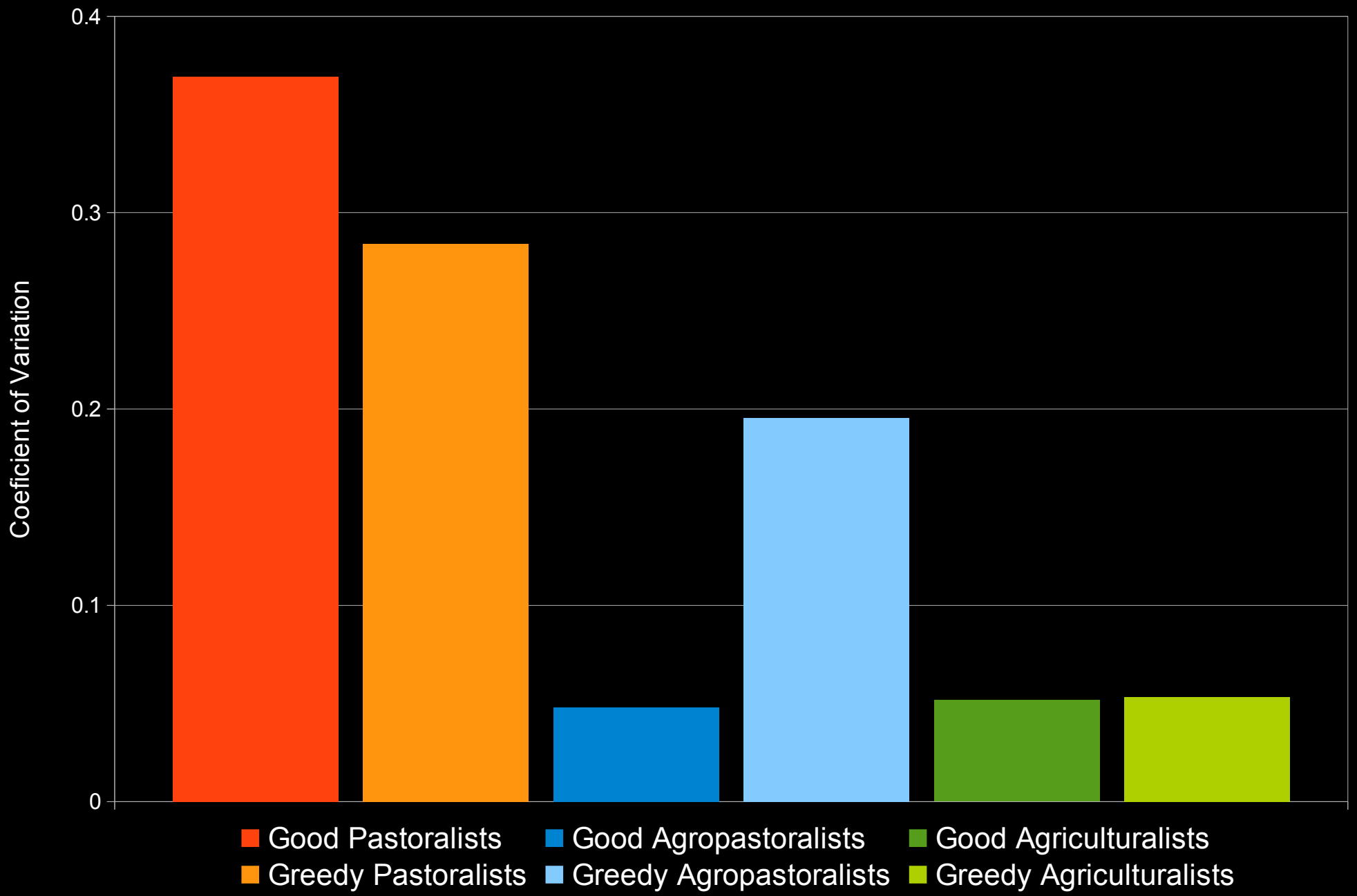


Figure 10

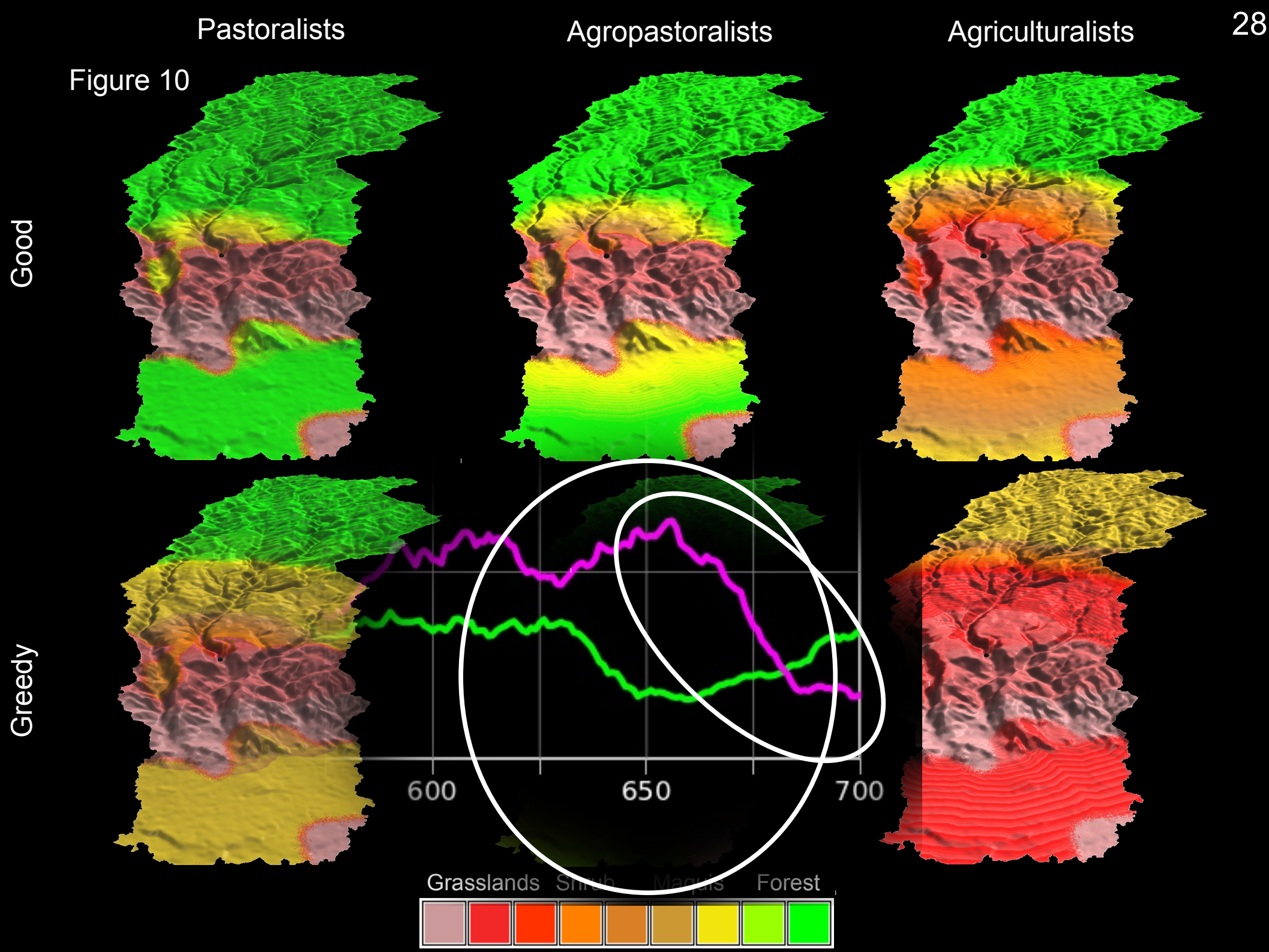
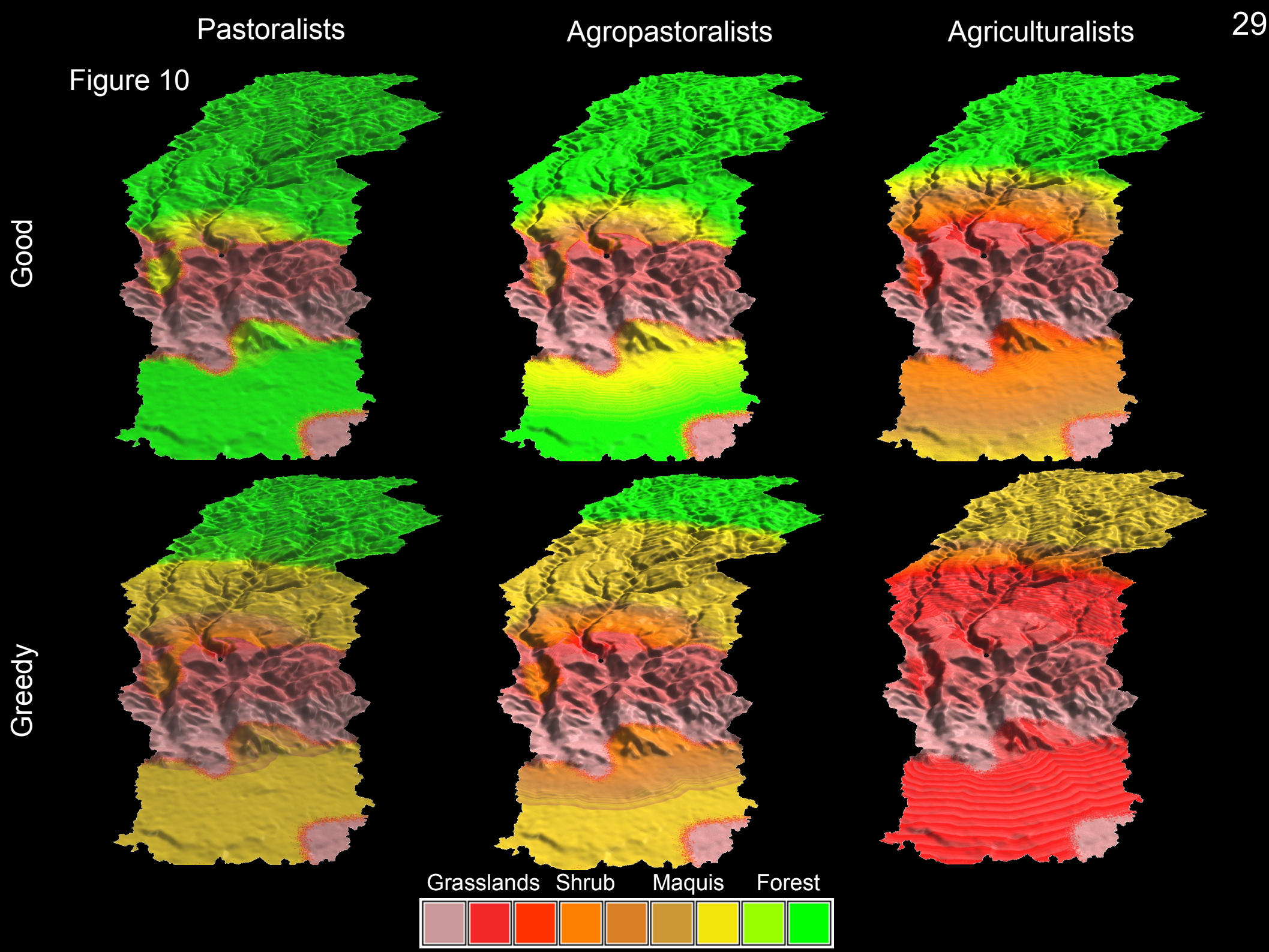
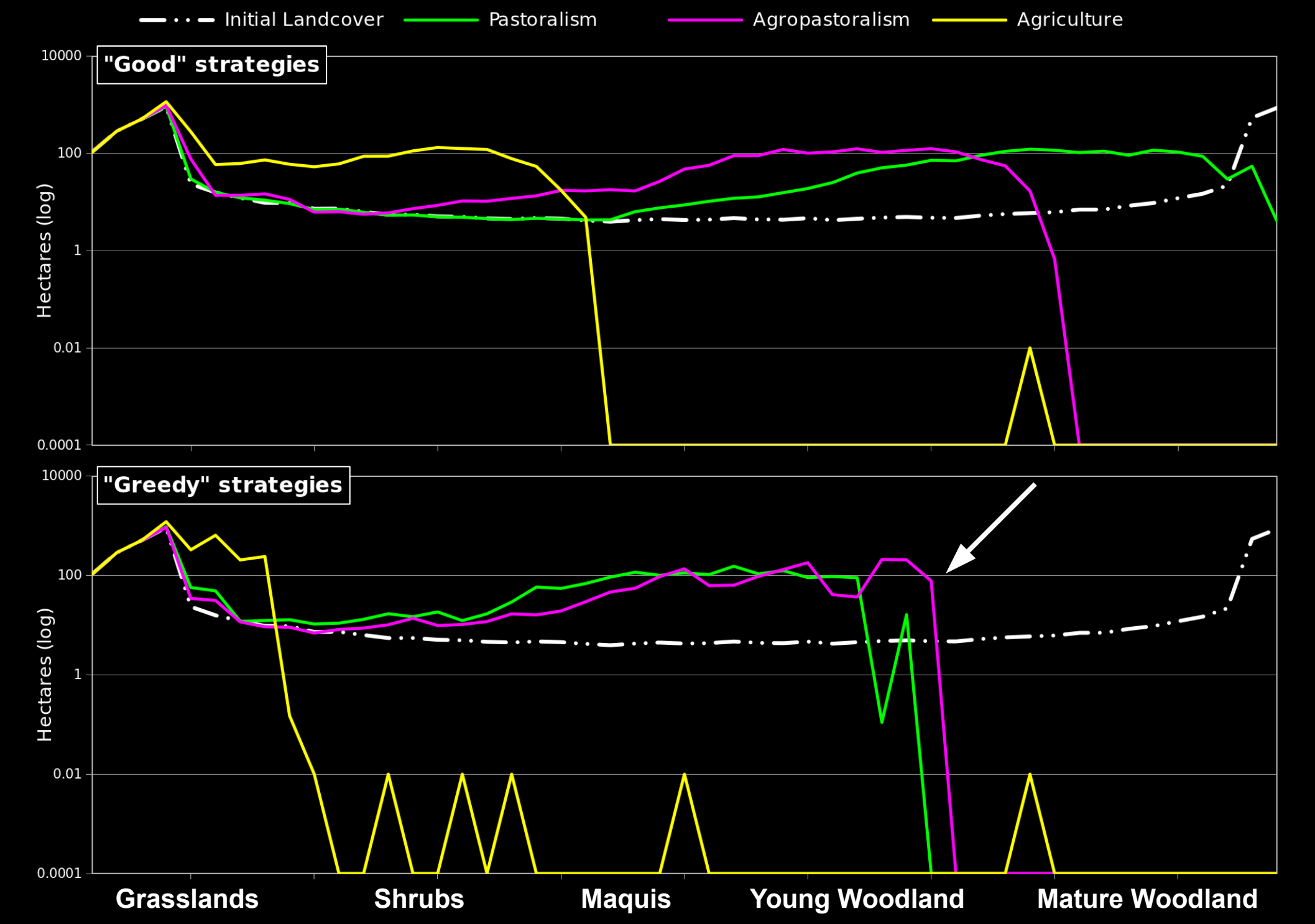

Pastoralists
Agropastoralists
Agriculturalists
Good
Greedy
600
650
700
Grasslands
Shrub
Maquis
Forest

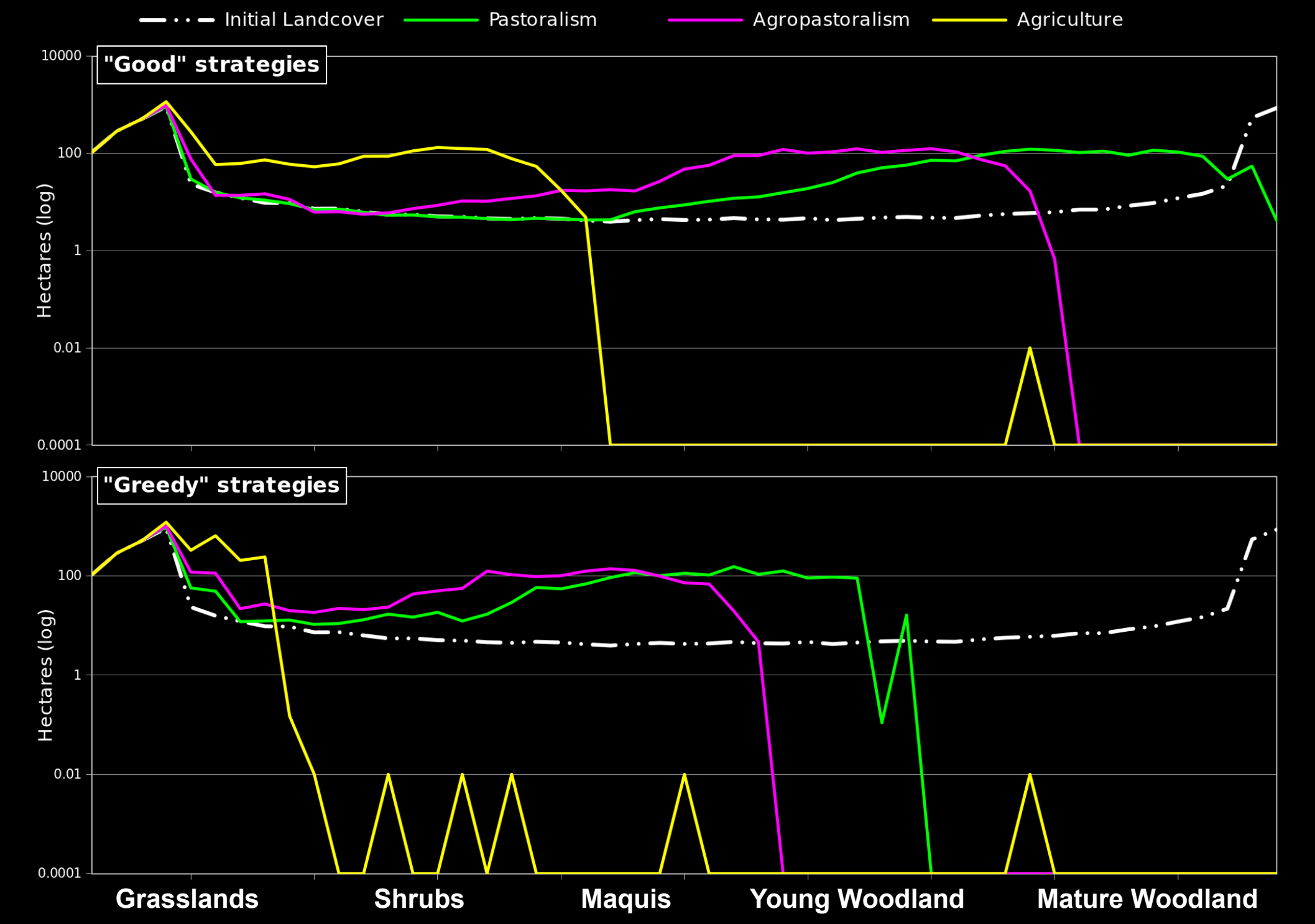
Figure 10


Pastoralists
Agropastoralists
Agriculturalists
Good
Greedy
Grasslands
Shrub
Maquis
Forest

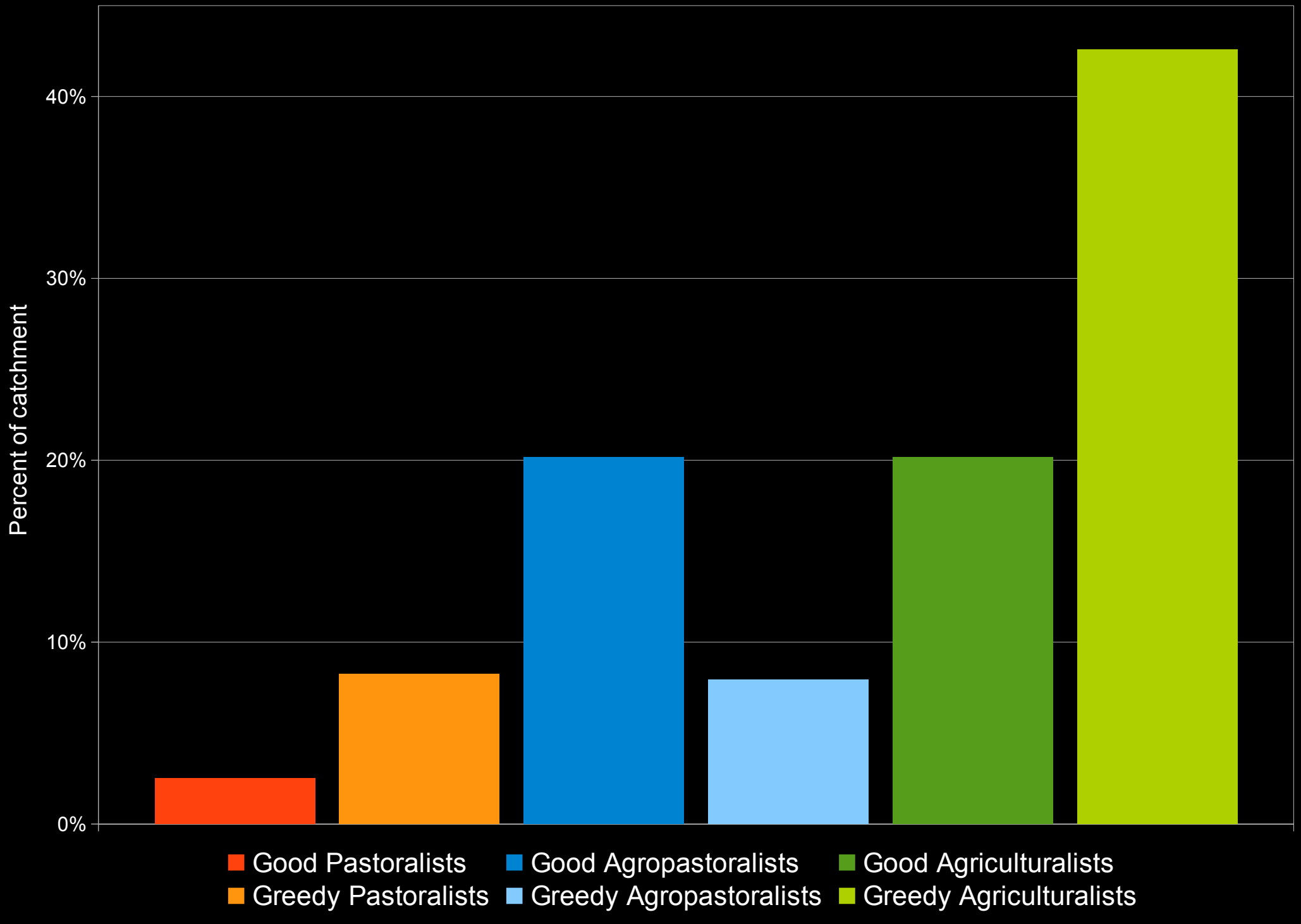
Extent of different landcover types within a 2-hour walking-cost catchment after 700 years



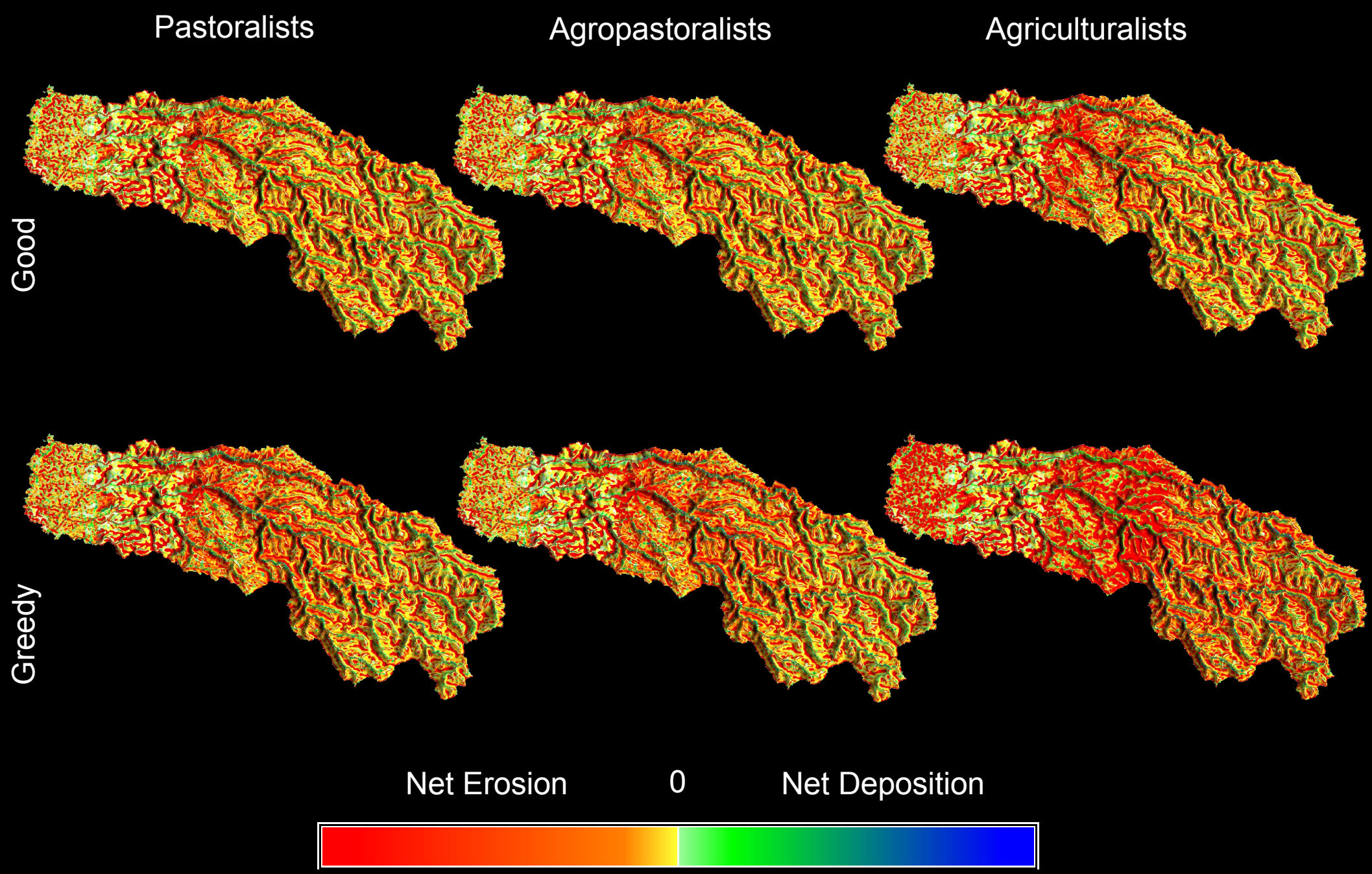
Extent of different landcover types within a 2-hour walking-cost catchment after 700 years



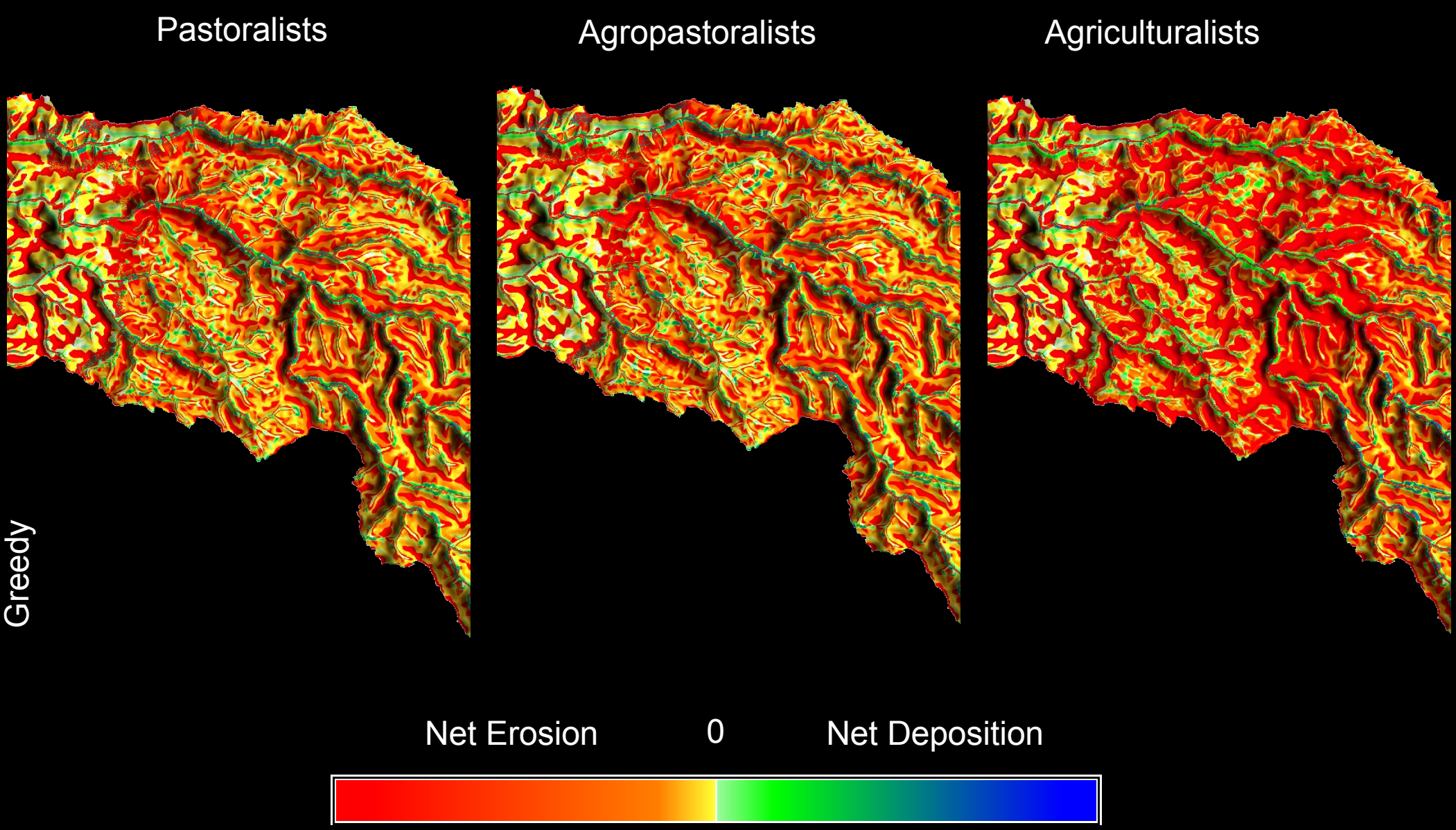
Percent of farmable land within a 2 hour walking-cost catchment with reduced fertility



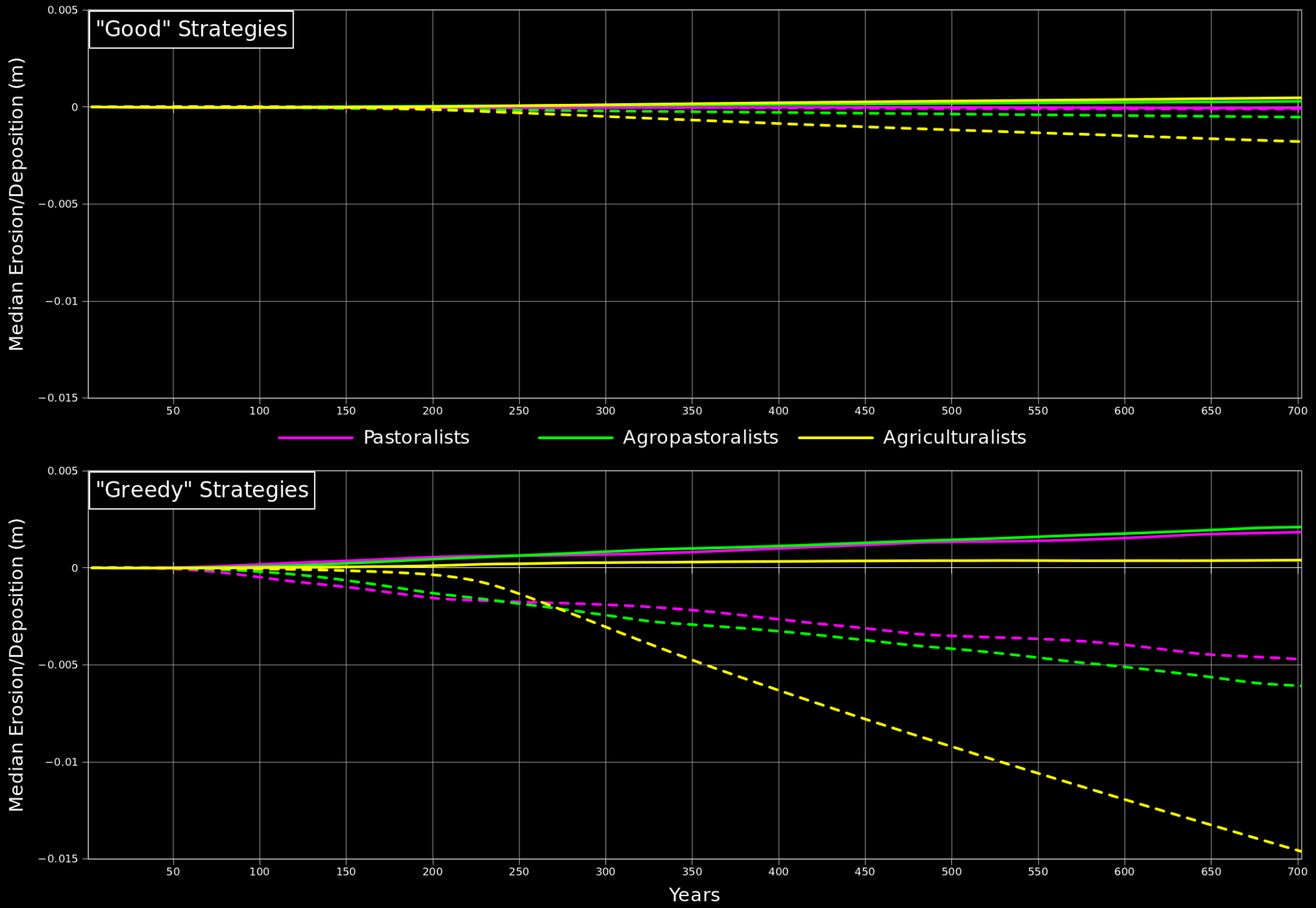
Cumulative Erosion/Deposition



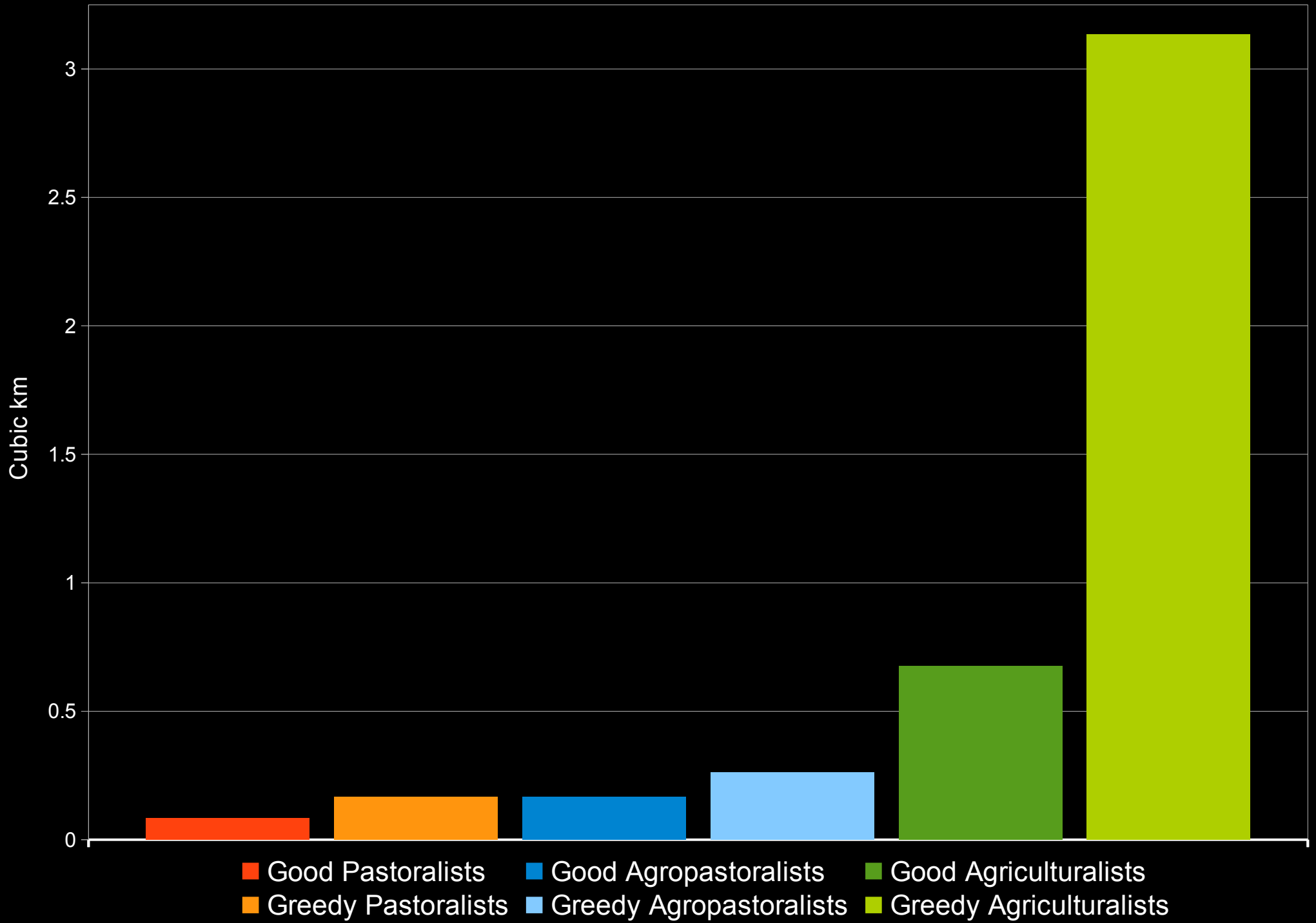
Cumulative Erosion/Deposition



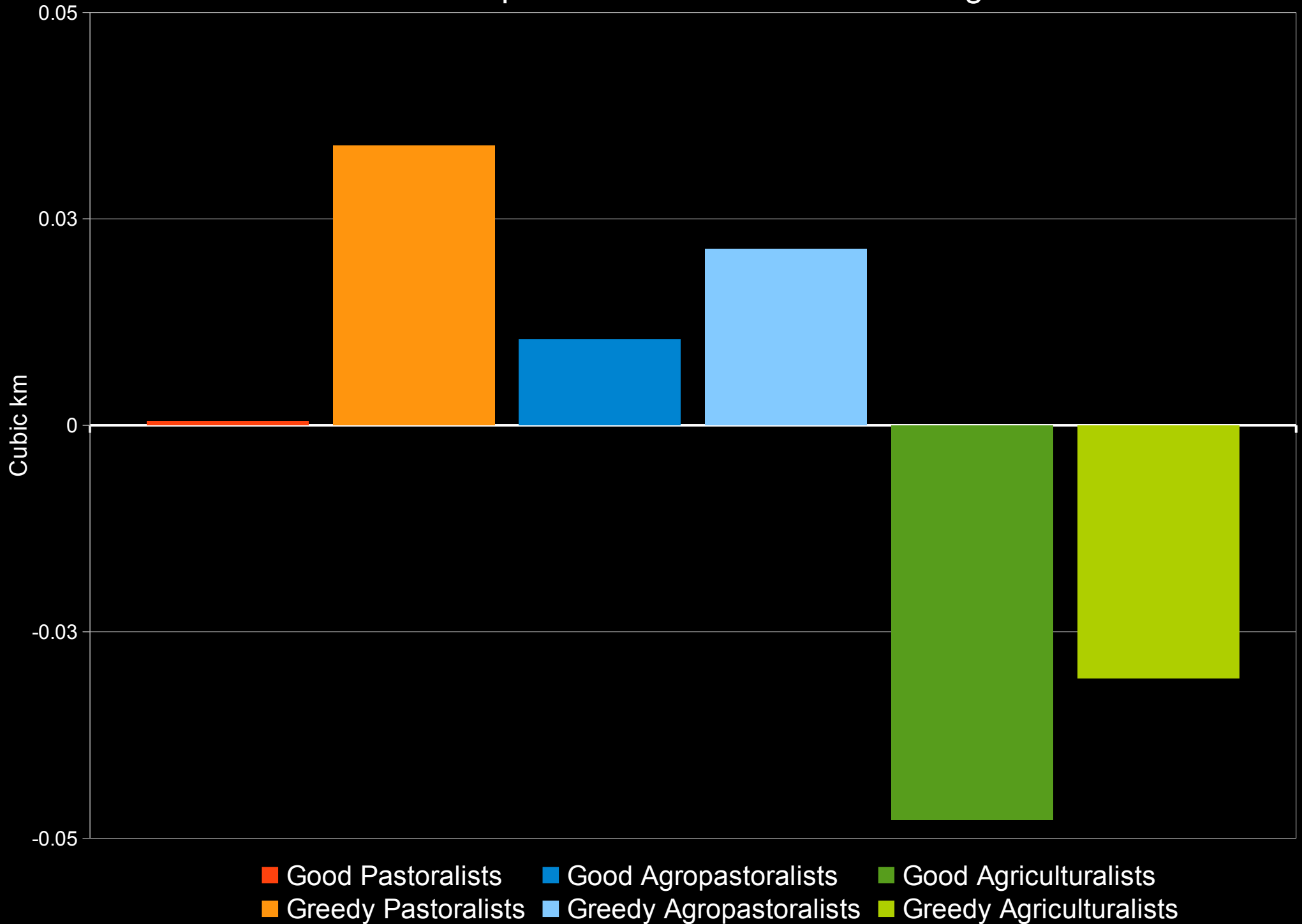
Cumulative Human Contribution to Erosion and Deposition Over Time



Human contribution to erosion within a 2 hour walking-cost catchment



Human contribution to deposition within a 2 hour walking-cost catchment



General Implications for PPN/LN Transition

1) Severe environmental degradation occurred in several of the scenarios, but only lead to a catastrophic population reduction in one ("greedy" agropastoralists).

2) Environmental degradation related *both* to degree of reliance on agriculture *and* the degree of "greediness".

3) Population variability increases with *both* degree of reliance on pastoralism *and* degree of "greediness".

4) Very large populations (600-1000 people) are only possible with high levels of agricultural dependence.

5) Equally mixed subsistence behavior, and being "good", is the only way to achieve *both* very high stability and low environmental impact.

The PPN/LN Transition in Wadi Ziqlab

1) Archaeological evidence suggests the Neolithic subsistence system in Wadi Ziqlab more similar to the “agropastoralists” or “pastoralists” of these simulations.

2) These simulations experienced high population variability ue to variability in the subistence base.

3) Thus, Banning's “Reduction of Variability” hypothesis seems to be the most likely motivator for the PPN/LN transition in the Wadi Ziqlab region.

4) Environmental degradation *could* have been a factor, however, but not necessarily.

5) Further simulations will examine if the switch to the dispersed LN settlement pattern would have mitigated the effects of resource variability on these agropastoral subsistence systems.

Thank you!

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