# 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

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# 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



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YBP	Period Name	
-7200 -7300 -7400	WadiRabah	
-7500		
-/600		
-7700		
-7900	Varmoukian	
-8000	Tarmo ukan	
-8100		
-8200		
-8300		
-8400		
-8500		
-8600	PNNC	
-8700	Late PPNB	
-8800		
-8900		
-9000		
-9100		
-9200		
-9400		
-9500		
-9600		
-9700		
-9800		
-9900		
-10000		
-10100		
-10200	Early PPNB	
-10300		
-10400		
-10500		

## **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



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WT4 - Tayiba Site

N

		a a llas	WZ120 - Tell Rakkan
	-200	WZ135 - Al Basitan	WZ300 - Al Aqaba
	0	A ALLANDA	WZ200 - Tabaqat al Buma
	200		A for the second of the second
	400		WZ121 - Tubna
	600	S.P.	CAR DO BALLANDER DE
41	800	1 1 1 m 1	Les de la company de la company
	1000		10 km
		A State State	

#### Timeline of the Neolithic in Wadi Ziqlab

<u>Years BP</u>	<b>Conventional Periods</b>	<u>Tell Rakkan 1</u>	<u>Tabaqat al-Buma</u>	<u>Al Basitan</u>
-6900 -7000 -7100			Site abandoned <mark>TAB – LN5 (no dates)</mark> Abandonment gap	
-7200 -7300	WadiRabah		TAB – LN4 (end not firm) TAB - LN3	Site abandoned?
-7400				AB – LN (all dates)
-7500				
-7700			TAB – LN2 (no dates)	
-7800				
-7900	Yarmoukian	Site abandoned?		
-8000		TR 1 – LN (no dates)	TAB – LN1 (beginning only constrained by PPNC)	
-8200				
-8300				
-8400				
-8500	PNNC	TD 1 DDND (begin ping		
-8700	Late PPNR	firm, end not)		
-8800	Laterrite	,,		
-8900				
-9000				
-9100				
-9300	Middle PPNB			
-9400				
-9500				
-9600				
-9700				
-9900				
-10000				
-10100	5 1 22112			
-10200	Early PPNB			
-10400				
-10500				

### **Tell Rakkan I**

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

100 meters

## **Tabaqat al Buma**

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

10 meters

## **Simulation Experiment Protocol**

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# **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

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Agent Environment Model Interaction Model System Settings	Agent Environment Model Interaction Model System Settings	Agent Environment Model Interaction Model System Settings
Map Selection Landscape Values	Villages Resources Households	Villages Resources Households
LANDSCAPE EVOL PARAMATERS	FARMING PARAMETERS Labor Required Initial Expected Yield Calories Provided	Birth Factors: Initial Percent Probability: 3 3 9 9 people per family
	(man-days/ha/year) (kg/ha/year) (kcal/kg)	Percent Probability Delta: 1 ( % (increase/decrease in a cycle)
Soil Density 1.25 R Factor 5.66 Infiltration 0.1 Kappa 1	WHEAT 50 450 3500	Minimum: 1 t % Maximum: 5 t %
Rain Days      100      Rain Value      0.5      Stream Transport      0.001      Load Exponent      1.5	BARLEY 51 456 3501	Death Factors:
cutoff 1 900 cutoff 2 11250 cutoff 3 225000 Smoothing Low \$	NOTE: Barley Is Only Consumed after Being Used as Fodder for Sheep and Goats	Initial Percent Probability: 2 3 ref 6 c people per family
		Percent Probability Delta: 5 🔅 % (increase/decrease in a cycle)
LANDSCAPE PARAMETERS	OVICAPRID GRAZING PARAMETERS	Minimum: 2 3 Maximum: 10 3 %
Soil Depth Minimum 0.5 Soil Depth Maximum 7	Number of Ovicaprids Per Person: 4 Ovicaprid Grazing Density Factor: 1	Percent of population providing labor: 80 🗘 % (rounded up to whole person)
Soil Fertility Impact 2 Soil Fertility Recovery 1	Ratio of Sheep to Goats:      Sheep :      I      To Goats :      I      Fallow Field Grazing:      ON      \$	Food required: 000000 kcal / capita / year Labor provided: 300 man-days / capita / year
	Annual Sheep Fodder Requirement 584 kg Annual Goat Fodder Requirement 894 kg	Maximum distance cost to travel to farm: 2800 Yield Expectation Scalar: 75
	Annual Caloric Yield per Sheep 0 kcal Annual Caloric Yield per Goat 0 kcal	0 25 50 75 100 125 150 175 200
Note: Allow your cursor to hover over any variable for more information		
GUI version 3.10, October 2010 Save Configuration Load Configuration (Validate ) (Initialize) (Cancel	GUI version 3.10, October 2010 Save Configuration Load Configuration (Validate) (Initialize) Cancel	GUI version 3.10, October 2010 (Save Configuration) (Load Configuration) (Validate) (Initialize) (Cancel)

## Modeling 6 Potential Neolithic Subsistence Systems

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	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	<u>Baladi Goat</u>	<u>Awassi Sheep</u>	
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	<u>Baladi Goat</u>	<u>Awassi Sheep</u>	
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 vield (kcal/kg):	3000	3540	Smith 2006 Fairbairn 1999
Maximum yields 7 (kg/ha):	2500	3500	Pswarayi et al 2008, Araus et al. 1998, 200
Wood gathering			
Wood need (kg/person):	2	000	Karanth 2006
Gathering intensity (kg/m <sup>2</sup> ):	0	.08	Karanth 2006

## Paleoenvironmental Reconstruction

# Reconstructing Neolithic Topography

"Clipping out" younger areas

\_\_\_\_\_ 10 km

## Reconstructing Neolithic Topography



#### Modern Topography

#### **Reconstructed Topography**

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#### Estimating Soil Depth From Topography







## **Reconstructing Neolithic Climate**



#### Climax vegetation – PPNB/C period

- I. Coastal Galilee
- Akko Plain
  Coastal Carmel
- 4. Sharon
- 5. Pleshet
- 6. Upper Galilee
- 7. Lower Galilee 8. Mt. Carmel









## Results

#### **Population Over Time**



Variation in population over 700 years



#### Variation in population after first population peak





Greedy



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



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## **Cumulative Erosion/Deposition**



## **Cumulative Erosion/Deposition**



#### Cumulative Human Contribution to Erosion and Deposition Over Time <sup>35</sup>



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





# General Implications for PPN/LN Transition<sup>38</sup>

- 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

- 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.
- 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.

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