Environmental Circumscription and the Emergence of Social Complexity

Stephen Scott

Department of Computational Social Science
George Mason University
sscotta@gmu.edu

Abstract. Carneiro proposes a theory for the emergence of social complexity that draws from ecological and biological inspiration. Key to this theory is the notion of "environmental circumscription", which posits that spatial, geographic, and social factors may induce competitive or cooperative interactions in otherwise independent social groups, resulting in acceleration in the rate of evolution of social complexity. An agent based model is used to investigate the effects of environmental circumscription on the emergence of complex interactive behavior among societies in the early stages of social complexity. The model results indicate no relationship between amount of habitable land and social complexity emergence speed or ethnic diversity. However, the results show that environmental variability does impact the social complexity emergence speed and ethnic diversity. Offering a new perspective on Carneiro's theory, the findings suggest that time rather than space may have more effect on the emergence of social complexity.
Keywords: Environmental circumscription, social complexity, agent-based modeling.

1 Introduction

Carniero (1970) introduces the idea of *Environmental Circumscription* as a way of explaining the role of environmental constraints on the emergence of social complexity, using contrasting examples from the Amazon basin and the Peruvian coastal valleys of South America. The motivation for the work in this project is to model the effects of spatial and environmental factors on the emergence of social complexity in early civilizations. This topic is of interest because it offers a way to explain why complex societies emerged in certain parts of the world and not in others. Carniero proposes that in an environment such as the Amazon basin where there is a large amount of unoccupied habitable land, conflicts between neighboring groups will lead to simple displacement of one group to a new area. This does not bring about any particular increase in social complexity, as the original and displaced groups continue life as they did before the conflict. In contrast, areas such as the Peruvian coastal valleys have relatively compact and highly geographically constrained areas of habitability, so conflicts between neighboring groups result in subjugation of one group by another. This invariably leads to greater social complexity such as a simple chiefdom, in which the dominating group extracts tribute such as crops or labor from the subjugated group. (Carniero, 1970).

There has been considerable interest and wide-ranging debate over the application of methods from ecology and biology to anthropology. Much of the discussion is focused on the role of evolution as a driving force for change in biological systems but not in human social systems, and on the role that human cultural features play as a significant force in social complexity that is not seen to any similar degree in animal populations (Richersen, 1977) (Abruzzi, 1996). The role of environmental stability in ecosystems and its effects on the emergence of species diversity in animal populations and social complexity in human populations have been considered by Abruzzi (1996), Hardesty, (1972) (1980), and Yellen (1977).

The Carneiro Environmental Circumscription theory examines variability in amount of habitable land and environmental fluctuations on the speed with which socially complex structures emerge. To investigate these features, an agent-based modeling approach is used to create an artificial landscape with varying amounts of habitable land and environmental stability. The major findings are that the amount of habitable land does not have an effect on the speed of emergence of complex social structures, but the amount of environmental fluctuation does have an effect.

2 Method of Analysis

2.1 Model Design and Development

A model was developed using the NetLogo agent-based modeling framework (Wilensky, 1999). The model was designed to provide an abstract environment for studying the effects of social interactions between small populations in a limited geographical area. The model includes a small number of population groups or "tribes" as might be found in an early hunter/gatherer society, initially randomly located on an artificial landscape that includes some fixed percentage of habitable land. Each tribe consists of a relatively small number of individuals, generally in the range of 10 to 75 members. Thus, these tribes represent small to medium sized hunter/gatherer clans or potentially extended families of a single clan.

Tribes grow in population size over time based on a logistic population growth model until the carrying capacity for their immediate territorial area is reached. When this occurs, the tribe splits into two smaller tribes, then one of the tribes attempts to migrate to the nearest available adjacent unoccupied area. If no such unoccupied area exists, the tribe migrates anyway, which sets up a land ownership conflict between the incumbent tribe and the newcomers.

The logistic equation used in this model to govern population growth is widely used in environmental and biological population studies (Case, 2000). In the logistic model, a population grows rapidly initially, declines in growth rate as the population nears the theoretical carrying capacity of its habitat, and eventually reaches a growth rate of zero when the carrying capacity is reached. Although not included in this modeling effort, realistic demographic models of population change usually employ more complex approaches, including models of the rates of births, deaths, emigration, and immigration as well as other factors in order to project future population sizes from available data (Rogers, 1985) (Schoen, 2006), (Davis, 1995).

Conflict between multiple tribes at a given land site is modeled as a simple contest of relative sizes: the larger of the competing tribes always wins. The rationale for this is based on the assumption that in early societies, the difference between the fighting capabilities among tribes was marginal, as both sides had access to similar weapons, tactics, and training. Consequently, the side that brings more warriors to the battlefield will prevail, all other things being equal. The outcome of conflict in the model is that the losing tribe is substantially reduced in population size, but the survivors are assimilated into the victorious tribe. The cost of victory includes some amount of population loss for the victor as well, which models combat losses incurred in the battle.

The model also includes random exogenous disasters that introduce stress into the population, such as severe droughts, flooding, crop failures, epidemics, and loss of livestock. These effects result in complete elimination of some number of tribes, simulating loss of life due to disease or lack of resources. These effects occur rarely, but when they do occur, they can have significant impact on the overall population size.

2.2 Key Features of the Model

The model contains several key features that affect agent behaviors and impact the results. These are summarized in **Error! Reference source not found.**.

Table 1. Key Model Parameters.

Key Parameter	Description (and typical values)
habitable-land	Percentage of habitable land in the artificial landscape (5% to 100%)
r	Intrinsic rate of reproduction for the population (% 4)
k	Carrying capacity – arbitrary upper limit for tribe/clan size (100 members per unit of habitable land)
likelihood	Probability that a catastrophic environmental event will occur at any given time step
loss	Severity of the impact of a catastrophic loss, if it occurs measured in percent of tribes/clans lost
ethnic-diversity-index	A measure of the relative ethnic diversity in the overall population. Values near 0 indicate dominance by one or a small group of clans/tribes, and values near 1 indicate more equitable dispersion of clans/tribes.

2.3 Experimental Design

Several experiments were conducted to examine the effects of habitable land availability and environmental variability on the speed of emergence of complex societies and the ethnic diversity exhibited during the process. The specific hypotheses for the study are as follows.

1. Increasing in the amount of habitable land will increase the time required for a complex society to emerge
2. Increasing the amount of habitable land will increase ethnic diversity
3. Increasing the amount of environmental variability will decrease the time required for complex society to emerge
4. Increasing the amount of environmental variability will decrease ethnic diversity

Experiment 1 was designed to study the effect of habitable land availability on social complexity and ethnic diversity in hypotheses 1 and 2. The amount of habitable land was allowed to vary from 5% to 100%, and measurements were made for the time required for a single ethnicity to dominate all others, as well as for the total ethnic diversity present. The model was configured to run for 10000 cycles, with an initial tribe count of 10, reproduction rate *r* at 0.04, catastrophic *likelihood* at 0.005, and *loss* at 0.01. Each setting was run 20 times, and when the model finished each run, the ethnic diversity index and final simulation time cycle values were recorded. Although the maximum number of cycles was set to 10000, the model could run to completion in fewer cycles, as is the case when one ethnicity dominates and eliminates all others, indicating an early emergence of social complexity such as a complex chiefdom.

Experiment 2 was designed to study the effect of environmental variability on social complexity and ethnic diversity in hypotheses 3 and 4. The amount of habitable land was fixed at three representative values, with a low amount of 10%, a medium amount of 50%, and a high amount of 90%. The model was configured to run for 10000 cycles, with an initial tribe count of 10, reproduction rate *r* at 0.04, and a catastrophic *likelihood* at 0.005. Unlike Experiment 1, however, the *loss* parameter was allowed to take the values in the set {0.01, 0.05, 0.10, 0.15, 0.20, 0.25} to explore various degrees of catastrophic environmental stress. Each setting was run 20 times, and when the model finished each run, the ethnic diversity index and final simulation time cycle values were recorded. As before, although the maximum number of cycles was set to 10000, the model could run to completion in fewer cycles, as is the case when one ethnicity rapidly dominates and eliminates all others, indicating an early emergence of social complexity such as a complex chiefdom.

3 Results and Findings

The results of the experiments show that variations in amount of habitable land do not have an effect on the speed of emergence of social complexity, nor on the ethnic diversity in the population. The results do show that environmental stresses have an effect on the speed of emergence of social complexity and on ethnic diversity.

For Experiment 1, the results show that there is no evidence that varying the amount of habitable land affects either the speed of emergence of socially complex organizations, nor the diversity of ethnic compositions of a population. This was not expected, as the Carneiro theory posits that land availability pressure in a region would drive a population towards more complex social arrangements. Figure 1 shows that despite wide variations in the amount of habitable land, there were very few cases in which a socially complex society emerged after 10000 simulated years, and in most cases the simulation simply ran to the maximum time period and ended without forming a complex chiefdom.

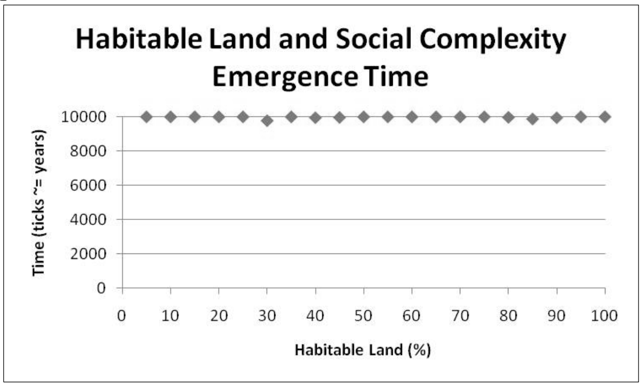

Figure 1. Habitable Land and Social Complexity Emergence Time

A One-Way ANOVA assessing the complexity emergence time for Experiment 1 confirms that at the 95% confidence level, there is no statistical basis to support hypothesis 1. Variations in habitable land produce an F value of 0.87, a P value of 0.625, and an R^2 of 4.15%.

Similar results are found when comparing the amount of habitable land with the overall ethnic diversity. Figure 2 shows that for widely varying amounts of habitable land, there is virtually no difference in the ethnic diversity of the population.

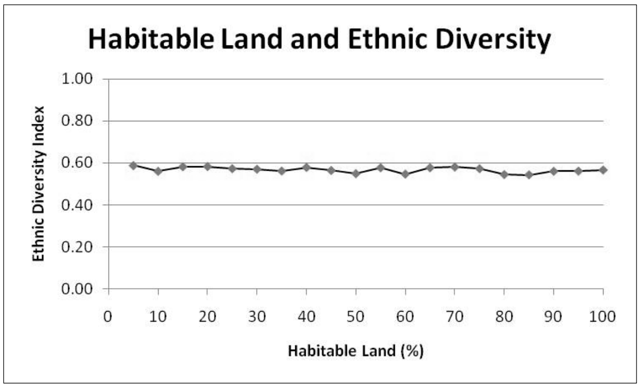

Figure 2. Habitable Land and Ethnic Diversity

A One-Way ANOVA of the ethnic diversity values for Experiment 1 confirms that at the 95% confidence level, there is no statistical basis to support hypothesis 2. Variations in habitable land produce an F value of 0.70, a P value of 0.817, and an R^2 of 3.39%.

For Experiment 2, the results show that there is a relationship between increasing levels of environmental variability and the speed of emergence of social complexity and the ethnic diversity. Figure 3 shows that for various amounts of habitable land, as the amount of environmental stress (expressed as the catastrophic magnitude) goes up, the time needed for one dominant group to emerge goes down.

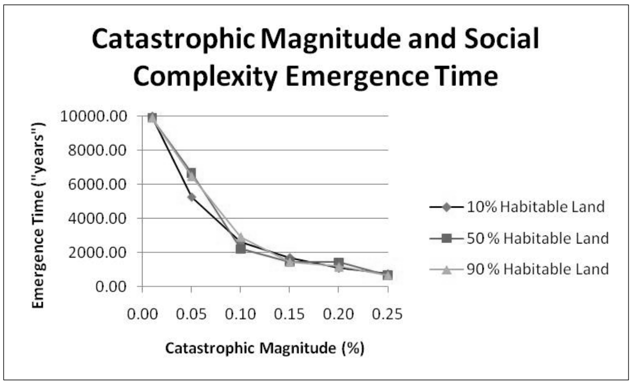

Figure 3. Catastrophic Magnitude and Social Complexity Emergence Time

A Two-way ANOVA used to assess the effects of habitable land and catastrophic magnitude on social complexity emergence time shows that at the 95% confidence level, variations in the amount of habitable land do not have a statistically significant effect, however, variations in the degree of catastrophic magnitude do. Variations in amount of habitable land produce an F value of 0.49 with a P value of 0.624, however, variations in catastrophic magnitude produce an F value of 279.79 with a P value of < 0.000. The R^2 value is 99.29%. The results support hypothesis 3.

Figure 4 shows the relationship between degree of catastrophic magnitude and the variability in ethnic diversity. As the level of catastrophic magnitude increases, there is a noticeable and sudden decrease in the amount of ethnic diversity.

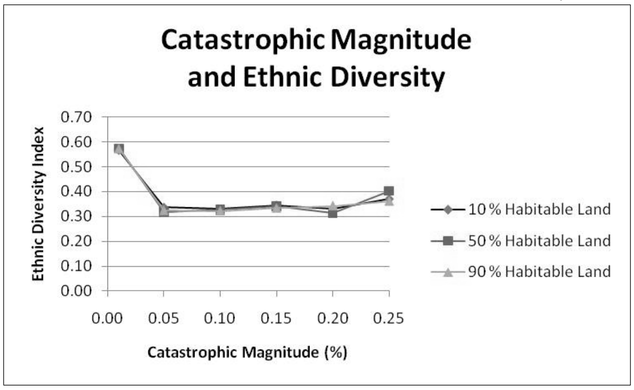

Figure 4. Catastrophic Magnitude and Ethnic Diversity

A Two-way ANOVA assessing the relationships between amount of habitable land and degree of catastrophic magnitude shows that at the 95% confidence level, variations in amount of habitable land do not have a statistically significant effect on ethnic diversity, but variations in the degree of catastrophic magnitude do. Variations in amount of habitable land produce an F value of 0.19 with a P value of 0.827, however, variations in catastrophic magnitude produce an F value of 167.12 with a P value of < 0.000. The R^2 value was 98.82%. The results support hypothesis 4.

4 Discussion

The results of Experiment 1 suggest that simple variations in the amount of available land in a region cannot account for the emergence of a complex chiefdom from hunter/gatherer social organizations. The model shows that even in the few cases where a more complex society did emerge, a long amount of time is required for a single tribe to emerge as dominant. The variation in ethnicities remained fairly high across various land availability values, suggesting that there was no single ethnicity that was able to dominate its neighbors. This appears to be contradictory to Carneiro's Environmental Circumscription theory, which predicts that cases in which there was little available land would lead to rapid conflict, the emergence of dominance relationships, and thus the evolution of higher degrees of social complexity.

The results of Experiment 2 suggest that in areas that are subjected to widely varying environmental pressures, there are noticeable effects on the speed of emergence of socially complex structures and the amount of ethnic diversity present in such conditions. The model shows that when the environment is stable from year to year, there is high ethnic diversity and little change over time. However, if the environment is unpredictable and causes large population losses, then there is much less ethnic diversity and fairly rapid convergence to a single dominant ethnic group.

5 Summary

This study has investigated the Carneiro Environmental Circumscription theory, focusing in particular on the speed of emergence of socially complex structures in early societies. The study examined societies experiencing variability in habitable land and environmental fluctuations, and investigated the likelihood that complex social structures would emerge under various geographic and environmental circumstances. The major findings are that the amount of habitable land does not have an effect on the speed of emergence of complex social structures, but the amount of environmental fluctuation does have an effect. The major implication is that for the Environmental Circumscription theory, the environmental component is more important than the circumscription component. The number of years of consistent environmental stability at a given location seems to have more effect on the propensity of a society to develop complex structures than the amount of habitable land available. This suggests that time rather than space is the more important factor governing the emergence of social complexity.

6 References

Abruzzi, William S. (1996) "Ecological Theory and the Evolution of Complex Human Communities." *Advances in Human Ecology*, 5:111-156.

Carneiro, Robert L. (1970). "A Theory of the Origin of the State". *Science*, New Series, Vol 169, No. 3947 (Aug 21, 1970). 733-738.

Case, Ted J. (2000) An Illustrated Guide to Theoretical Ecology. Oxford University Press, New York.

Cioffi-Revilla, Claudio. (2005). "A Canonical Theory of Origins of Social Complexity". *Journal of Mathematical Sociology*, 29:133-153.

Davis, H. Craig. (1995). Demographic Projection Techniques for Regions and Smaller Areas: A Primer. UBC Press, Vancouver, Canada.

Hardesty, Donald L. (1972) "The Human Ecological Niche". *American Anthropologist*, New Series, Vol. 74, No. 3 (Jun., 1972), pp. 458-466.

Hardesty, Donald L. (1980) "The Use of General Ecological Principles in Archaeology". *Advances in Archaeological Method and Theory*, Vol. 3 (1980), pp. 157-187.

Richerson, Peter J. (1977) "Ecology and Human Ecology: A Comparison of Theories in the Biological and Social Sciences". *American Ethnologist*, Vol. 4, No. 1, Human Ecology (Feb., 1977), pp. 1-26.

Rogers, Andrei. (1985) Regional Population Projection Models. Sage Publications, Beverly Hills, CA.

Schoen, Robert. (2006) Dynamic Population Models. Springer, Dordrecht, The Netherlands.

Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Yellen, John E. (1977) "Long Term Hunter Gatherer Adaptation to Desert Environments: A Biogeographical Perspective." *World Archeology* 8:262-274.