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The Effect of Landscape Patterns on Foraging Strategies of Hunter-Gatherers: An Empirical Agent-Based Modeling Approach

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***Abstract*—An empirically grounded model of Ache hunter-gatherers was used to test the performance of alternative foraging strategies for different distribution of resources.**

I. Introduction

We developed an agent-based model of foraging behavior based on ecological parameters of the environment and prey characteristics measured in the Mbaracayu Reserve Paraguay (Janssen and Hill, 2014; see also model documentation: http://www.openabm.org/model/3902/version/2/view). The model was implemented on 58,408 one-hectare cells using a time step of 5 minutes for an average of 6-hours-per-day hunting activities for one year. We then compare estimated foraging behavior from our model to the ethnographically observed behavior of Ache hunter-gatherers who inhabit the region and show a close match for daily harvest rates, time allocation, and species composition of prey. The model allows us to explore the implications of social living, cooperative hunting, variation in group size and mobility, under Ache-like ecological conditions. Simulations show that social living decreases daily risk of no food, but cooperative hunting has only a modest effect on mean harvest rates. Analysis demonstrates that bands should contain 7-8 hunters who move nearly every day in order to achieve the best combination of average harvest rates and low probability of no meat in camp.

In this extended abstract we will extend the analysis by exploring the hunting behavior on diverse landscapes. The Ache landscape has similar return rates for each of the seven vegetation types. This explains why random walk is such a good null model. However, many landscapes are more patchy, meaning that resources are clustered is certain areas. So, how sensitive is the hunting strategy of the Ache to alternative landscapes? We vary the original Ache landscape by including vegetation patterns and distribution of species among vegetation types, while keeping the expected food availability the same. We expect that more concentrated resources lead to more targeted movements of the groups, and more prolonged stay in higher productive areas.

TABLE I
Table 1: Types of landscapes

Clumpiness	Original Variation Quality	High Vegetation Quality
Low		
Original	**Original**	
High		

II. Hunting Strategies

The default strategy that agents use is to randomly define in the morning a location for the camp to move to in the evening that is 2 kilometers from the current camp location. Agents move towards the camp in a U-shaped pattern. Agents coordinate their movements such that they can execute cooperative hunting. This means that they walk through the forest within a distance of a few hundred meters. Although this clustering of hunters will suppress encounters of prey (due to hunter A scaring animals away for hunter B in the same area), the opportunity of cooperative hunting increases performance.

In the targeted camp version of the model, agents move towards a camp location with preferred vegetation type. We keep track where each camp has been. We don‘t want agents going to the neighboring patch if it will move, so we assume that a camp has an area of influence. We define that the new camp needs to be at least 1 km away from the old location. When a camp moves it will look for the nearest riparian patch (the vegetation type with the highest return rate) which has not been visited during the last 30 days, which is a kind of recovery period. If there is no patch available, we will look for available patches with high forest.

When the direction is defined, we will check whether the target is between 1 and 3 km. If so, the new camp location will be the target level. Otherwise, the camp will move 2 km in the direction earlier defined.

The original Ache model assumed agents move camp locations after a certain amount of days (say one day). In the adaptive camp version of the model, the agents in a group consider whether the average weight of meat hunted is above a certain threshold. If so, the agents stay, if not, the agents move on.

We run 64,800 simulations with the Ache model, 100 runs for each of the about 108 configurations on each of the 6 landscapes where we vary adaptive/non-adaptive camp, targeted/non-targeted camp, the group size and the threshold when an adaptive camp is abandoned.

III. Creating Alternative Landscapes

The next step is to change the distribution of encounter rates. We multiply the encounter rates of riparian by about 3 and those of the high forest by 2. The other vegetation types are multiplied by about 1 or lower to make sure that the encounter rates over the whole landscape remains the same for each species. The multipliers lead to a more unequal distribution of expected return rates for the vegetation types. The figure below is based on calculations of the null model (thus no cooperative hunting). We see now that riparian is more than ten times as productive as the meadow.

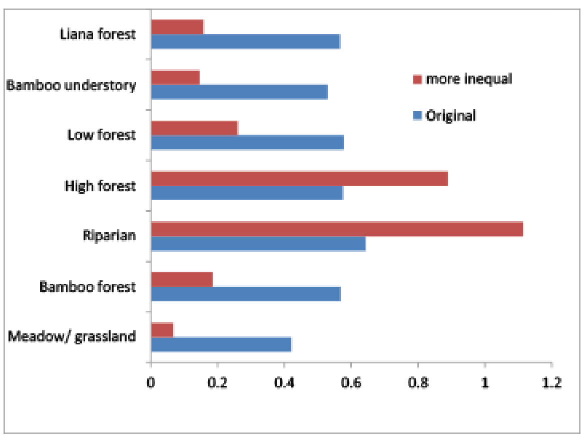

Fig. 1. Expected return rates of one hour of hunting on the 7 vegetation types with the original distribution and with the encounter rate distribution that leads to higher vegetation variability.

We vary the landscape by changing the configuration of vegetation types. We want to see what happens if we have more concentrated blobs of the same vegetation. We take the original landscape and perturb this by including an algorithm which checks if randomly swapping the land cover of two cells leads to a higher degree of different types of vegetation on direct neighboring cells. We can also go the other direction and see whether we can make the landscape more random. In the original landscape a patch has on average from the 8 neighboring patches 60% of the same vegetation type. We explored the consequences for landscapes with 30% and 90% of the neighbors with same vegetation type.

IV. Analysis

We ran for each of the 6 landscapes, 108 strategies 100 times for each parameter setting. We see that for non-patchy landscapes the best strategy is that groups move each day (Table 2). When the landscape is patchy a non-adaptive

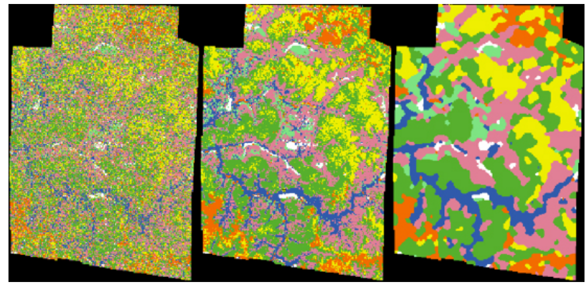

Fig. 2. Vegetation maps for less clumpy landscape, original landscape, and more clumpy landscape (right).

movement is best when the vegetation is distributed more randomly (clumpiness is low). Groups go to most productive vegetation types (targeted camp) except when vegetation types are more randomly distributed (similarity = 30%).

In all landscapes we find that 7 hunters is the optimal strategy. Perhaps this number is defined also for other landscapes by the encounter suppression assumptions (see Janssen and Hill, 2014). The optimal strategy for the Ache landscape is that groups target the more profitable vegetation types and move each day.

If landscapes are more patchy than the Ache landscape and vegetation types are more concentrated, movement of groups is more adaptive. When vegetation is more clumpy we also see that the minimum kg of meat caught required for a camp to stay in the same location becomes higher.

TABLE II
Table 2: Optimal strategies for different landscapes.

Clumpiness	Original Vegetation Variability	High Vegetation Variability
Low	Non-targeted camp, 7 hunters, non-adaptive camp	Non-targeted camp, 7 hunters, non-adaptive camp
Original	Targeted camp, 7 hunters, non adaptive camp	Targeted camp, 7 hunters, adaptive camp. Threshold = 2kg
High	Targeted camp, 7 hunters, non-adaptive camp	Targeted camp, 7 hunters, adaptive camp. Threshold = 2.5kg

In Table 3 we present the meat per hunter per day for different strategies. The average meat per hunter per day remains the same if species are distributed equally among vegetation types (OVV) independent of the strategy. If species are more concentrated in riparian and high forest (HVV), we see that the average meat per hunter per day increases sharply for the optimal strategies if vegetation becomes more concentrated. In contrast the Ache hunting strategy will not do well in landscapes where resources are more concentrated in specific vegetation cells.

To conclude, the distribution of resources on the landscape affects which hunting strategies are most effective. This is not surprising, but this empirically based model analysis shows that the Ache hunting strategy is not effective if the relevant animal species are concentrated in a few small areas within the

TABLE III
TABLE 3: MEAT PER HUNTER PER DAY (KG/DAY) OF OPTIMAL STRATEGY AND FRACTION OF DAYS WITHOUT MEAT.

	Null model	Ache strategy	Optimal strategy
LC/OVV	2.96 / 0.531	2.85 / 0.041	2.85 / 0.041
OC/OVV	2.99 / 0.531	2.83 / 0.041	2.87 / 0.049
HC/OVV	2.96 / 0.531	2.84 / 0.041	2.86 / 0.051
LC/HVV	2.83 / 0.559	2.79 / 0.049	2.79 / 0.048
OC/HVV	2.83 / 0.561	2.79 / 0.049	3.18 / 0.045
HC/HVV	2.84 / 0.561	2.67 / 0.125	3.84 / 0.026

landscape. In all other landscapes the Ache hunting strategies performs close to the optimal strategy.

V. REFERENCES

Janssen, M.A. and K. Hill (2014) Benefits from grouping and cooperative hunting among Ache hunter-gatherers: Insights from an agent-based foraging model (to be submitted to *Human Ecology*).