# ODD + D Protocol ForeGatherer Model v1.0

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We provide a technical description of the model by applying the ODD + D protocol, which was originally developed by Grimm et al. (2010) and later extended by Müller et al. (2013) for models of human decision making.

## Overview

The model simulates the gathering behavior of recent hunter-gatherers.

### Purpose

The main focus is to explore the impact various technological and/or social scenarios have on foraging to study the gathering behavior of early hominins. The broad range of potential adaptations allows paleoanthropologists to study various time frames and hominin species and analyze how the behavior changes under varying conditions.

### Entities, state variables and scales

Each cell represents 1 km² in geographical space with a certain amount of a specific usable resource in an environment.

Two different types of agents exists performing different roles; the base agent serves as a camp while the foraging agents represent individual gatherers that start and end their day at the base camp. They use the available time of the day to gather edible resources in the surrounding area to cover a certain energy demand.

All parameters of the environment are listed and described in Table 1, all parameters of the agents are described in Table 2. Visualization parameters are listed in Table 3. They determine what is visible in the simulation view and have no effect on the simulation results. The functions of the buttons in the interface are listed in Table 4.

Table 1. Environment and cell parameters

| Name | Type of parameter | Brief description |
|---|---|---|
| *aseasonal-resource-value* | global factor | energetic value of 1 unit of aseasonal resource |
| *average-available-plants* | global response | mean energy value of the cells in the foraging range, used by foragers to detect periods of low resource availability |
| *day* | global response | counts overall passed days |
| *day-counter* | global response | counts days of the month |
| *distance-base* | cell response | distance between cell and current location of the base camp |
| *dry-season-amount* | cell factor | usable resources per month during the dry season |
| *dry-season-dataset* | global factor | allows the input of acsii map data to distribute resources during the dry season; requires *scenario* = “ASCII-map” |
| *dry-season-energy* | cell factor | Energetic value of the usable resources per month during the dry season |
| *habitat* | cell factor | occurring resources at the cell |
| *hours-per-day* | global factor | time available per day |
| *length-dry-season* | global factor | number of months with reduced resource availability |
| *map-aseasonal-resource* | global factor | ratio of aseasonal resource in the environment; default = 70% |
| *map-seasonal-resource* | global factor | ratio of seasonal resources in the environment; default = 30% |
| *mobility-value* | cell response | evaluation of the cell by the base camp for residential moves: (energy-amount * (distance-base * 2)) |
| *month-counter* | global response | counts months of the day |
| *net-primary-productivity* | global factor | basic yearly net-primary-productivity, divided by 12 for monthly net-primary-production. |
| *npp-multiplicator* | global factor | transforms net-primary productivity into resource availability; default = 30 |
| *pcolor* | cell constant | built-in NetLogo variable which holds the color of the cell which is determined by the map coloring factor (map-coloring) |
| *plabel* | cell constant | built-in NetLogo variable which holds the label text of the cell; not used in the present model |
| *plaber-color* | cell constant | built-in NetLogo variable which holds the color of the label of the cell; not used in the present model |
| *productivity-reduction-dry-season* | global factor | percentage the monthly usable resources gets reduced during the dry season |
| *pxcor* | cell constant | built-in NetLogo variable which holds the x-position of the cell on the map |

| | | |
|---|---|---|
| *pycor* | cell constant | built-in NetLogo variable which holds the y-position of the cell on the map |
| *rainy-season-amount* | cell factor | usable resources per month during the wet season |
| *rainy-season-dataset* | global factor | allows the input of acsii map data to distribute resources during the rainy season; requires *scenario* = "ASCII-map" |
| *rainy-season-energy* | cell factor | Energetic value of the usable resources per month during the wet season |
| *ran-seed?* | global factor | random factor or use a fixed seed number; default = Yes |
| *scenario* | global factor | available environmental scenarios;<br>default = "random-map" |
| *seasonal-resource-value* | global factor | energetic value of 1 unit of seasonal resource |
| *seed* | global factor | used to set a fixed seed if desired |
| *time* | global response | remaining hours of the day |
| *movement-border* | cell response | depicts if the cell is currently at the border of the movement-range |
| *visited-value* | cell response | depicts if the cell has been visited by agents |
| *year-counter* | global response | counts years of the run |

Table 2. Agent parameters

| **Name** | **Type of parameter** | **Description** |
|---|---|---|
| *breed* | agent constant | built-in NetLogo variable which holds the breed of the agent; allows to create different types of agents (base or foraging agent) |
| *capacity* | global factor | maximum amount of resources a forager can carry; default = 1500 |
| *color* | agent constant | built-in NetLogo variable which holds the color of the agent; color = red |
| *energy* | agent response | current energy in kcal |
| *energy-demand-per-day* | global factor | energy demand each forager has to cover |
| *food* | agent response | energetic value of the gathered resources after it has been processed |
| *function* | agent constant | holds the occupation of the agent; function = base or forager |
| *gathered* | agent response | resources currently carried by the agent |
| *heading* | agent response | built-in NetLogo variable which holds the direction of movement of the agent |
| *hidden?* | agent constant | built-in NetLogo variable which allows switching the visualization of agents on or off; hidden? = False (agents are visible) |
| *hunger* | agent response | signals exploitation of the surrounding |
| *label* | agent constant | built-in NetLogo variable which holds the label text of the agent; label = "" (no label) |
| *label-color* | agent constant | built-in NetLogo variable which holds the color of the label: label-color = black; labels are not used in the model |
| *number-of-foragers* | global factor | number of foragers in the group; default = 30 |
| *pen-mode* | agent constant | built-in NetLogo variable which holds the mode of the mark of the agent; not used in the |

| | | |
|---|---|---|
| | | present model |
| *pen-size* | agent constant | built-in NetLogo variable which holds the size of the mark of the agent, when *pen-down* is activated; not used in the present model |
| *shape* | global constant | built-in NetLogo variable which holds the shape of the agent; shape = “person” |
| *size* | global constant | built-in NetLogo variable which holds the size of the agent visualization; size = 1 |
| *storage* | global factor | resources stored by the base camp |
| *storage?* | global factor | determines if group can storage food at all; default = No |
| *storage-decay* | global factor | if the group can storage, they lose a certain percentage from the storage |
| *time-moved* | agent response | used by foragers to control movement during one hour |
| *way-to-new-basis* | agent response | distance to the new location of the base camp |
| *who* | agent response | built-in NetLogo variable which holds the ID of the agent |
| *work* | agent response | action of the agent, e.g. “base” or “wandering” |
| *xcor* | agent response | built-in NetLogo variable which holds the x-position of the agent on the map |
| *ycor* | agent response | built-in NetLogo variable which holds the y-position of the agent on the map |

Table 3. Visualization parameters

| **Name** | **Type of parameter** | **Description** |
|---|---|---|
| *show-habitat?* | global factor | holds which terrestrial map type is visualized: resources or habitat based on elevation |
| *pen-down-base?* | global factor | activates the built-in Net-logo pen-down function |

Table 4. Buttons

| **Name** | **Description** |
|---|---|
| *go* | runs the simulation until *max-simulation-duration* is reached |
| *setup* | calls the *setup* procedure |

A cell represents 1 $km^2$ of real space and 1 time step, which we refer to as „*tick*“, represents 1 hour of real time. A day has a duration of 12 hours. Resting time in the base camp is not included in the simulation.

## Process overview and scheduling

With the setup of the model the basecamp is established in the center of the map. During the remaining run the base agent acts as a place for the foraging agents to meet, store and share resources. If the storage is empty the base agent searches for a new location and moves with the group. The distance to the old location will be twice the longest distance of a logistical trip.

All foraging agents use the available time of the day to gather edible resources in the surrounding area to cover an energy demand they have to fulfill each day. The foraging agents search for resources by walking in a randomly chosen direction. When they gathered a sufficient amount of resources, they store the surplus in the base camp where they can be consumed by other foraging agents. Foraging agents spend the remaining time in the camp.

## Design Concepts

### Theoretical and empirical Background

The environment is a simplified landscape of 100 x 100 km offering exploitable resources. The main interaction between agents and the environment is the gathering of available resources.

The amount and the type of resource which occurs per cell is randomly distributed. The "*net-primary-productivity*" is used to estimate the minimum amount of newly generated plant mass during a particular month (Lieth, 1976). The resource amounts at each cell differ, as the availability randomly deviates by up to 10%.

Each month the resources on exploited cells are replenished. If a cell was not exploited, it keeps the same amount of resources. The availability of resources changes seasonally with the duration of each season being adjustable. At the beginning of a new season resources on an unexploited cell may be lost if the amount of usable resources during the beginning month is lower compared to the previous one.

The behavior of the agents represents the foraging behavior of recent hunter-gatherers. The foragers perform central-place foraging and carry resources to the base camp. The gathering process is simplified, foragers located at a cell with resources can start gathering. The amount of gatherable resources depends on the availability of resources and the maximum amount the forager can carry ("*maximum-load*").

## Individual decision-making

The foragers move into a random direction until they arrive at a cell with an excess amount of resources compared to the maximum amount they can carry. During the special occasions of low resource availability compared to the maximum load, the foragers also gather at cells with more resources compared to the average amount of plants (average-available-plants). To prevent the foraging agents from walking too far, a movement-border is calculated. Foraging agents need to stay at the base camp at the end of each day. Therefore, they compare the time travelled with the remaining hours in order to stop foraging and return in time.

The base agent searches for a new central place with twice the distance of the daily logistical movement ensuring that the area around the new camp is unused.

## Learning

In the basic version 1.0 of the model, the agents do not learn.

## Individual

## Sensing

Base agents perceive all cells when deciding where to move next.

## Stochasticity

The environment is randomly generated. Each terrestrial cell contains one type of resource that dominates the resource spectrum of this cell. The ratio in which both resource types occur can be adjusted (“*map-seasonal-resource*” & “*map-aseasonal-resource*”). The amount of resources are distributed around the monthly net-primary-production (“*net-primary-production*” / 12) with a maximum deviation of 10%.

## Observation

It is possible to collect a wide variety of data during each run of the model. These variables are already used to compare various mobility strategies of recent hunter gatherer groups (Kelly, 1983).

Table 5. Model Responses

| **Residential Mobility:** | | |
|---|---|---|
| Name | In-Model variable | Description |
| Number of residential moves per year | *number-res-moves-year* | Every change of the base location per year is counted as a residential move. |
| Average distance per residential move | *distance-res-move-year* | The distance of every residential move is calculated cumulatively and divided by the number of residential moves. |
| Total distance covered through residential mobility per year | *covered-distance-year* | The average distance per residential move is multiplied by the number of residential moves per year. |
| Total area covered per year | *covered-area-year* | Area covered by the group over the whole year. In the model every cell that was visited is counted, independent if the cell was visited during a residential or logistical movement. |
| Length of occupation of a winter (or rainy season) site | *longest-base-year* | Measured in days. |
| ***Logistical Mobility*** | | |
| One-way distance | *distance-log-moves-year* | Average distance moved during per logistical movement, determined by calculating the mean distance of all logistical movements. |
| ***Foraging success*** | | |
| Average yield | *average-yield-trip*<br>*average-yield-hour* | Average yield per foraging trip and per hour spent foraging |
| Diet composition | *percentage-seasonal-resource*<br>*percentage-aseasonal-resource*<br>*percentage-seasonal-resource-dry*<br>*percentage-aseasonal-resource-dry* | Percentage the two resources contribute to the energy overall consumed during the year or during the dry period |
| Energy lost from storage | *daily-storage-decay* | Energy lost per day from the storage due to the decay in energy-units/day |

# Details

## Implementation Details

The model is implemented in NetLogo 6.3.0 (Wilensky, 1999).

## Initialization

The configuration of the environment is determined by the selected scenario ("*random-map*" or "*ASCII-map*"). The resource amount is based upon the "*net-primary-productivity*" and "*npp-multiplicator*", while the seasonality is controlled by choosing the length and intensity of the dry season ("*length-dry-season*" & "*productivity-reduction-dry-season*"). At last the occurrence of the two resource types has to be chosen ("*map-seasonal-resource*" & "*map-aseasonal-resource*"). The group starts with an already established base camp at the Center of the map.

## Input Data

The "*random-map*" scenario does not need any input data. But the model allows to base the resource distribution on 2 ASCII data files using the "ASCII-map" scenario. The two files need to be named "rainy-season.asc" & "dry-season.asc" to be applicable in the model.

## References


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