**ODD Protocol**

**OUTLAND: OrangUtan simuLAtioN model**

The model description follows the ODD (Overview, Design concepts, Details) protocol for describing individual- and agent-based models (Grimm et al. 2006), as updated by Grimm et al. (2020).

1. **Purpose and patterns**

The Purpose of the model is to simulate the effect of changes in forest structure to the locomotion behaviour of orangutans. The grade of forest changes are defined by the tree density, crown size, and diameter-at-breast-height (dbh). The locomotion behaviour of orangutans to be observed are brachiation, sway, climb / descent, and walking.

Patterns:

One pattern that is observed in the nature and would be compared to the model output is the proportion of movement types that is carried out by orangutans. In a study carried out by Manduell and colleagues in 2012 (Manduell, 2012; Manduell et al., 2012), the type of locomotion that is observed in the nature varies with different level of tree density. For example, in a forest with higher tree density, the locomotion type that is much more observed is the sway and brachiation movement. Whereas in a forest with lower tree density, the locomotion type that is often found is walking on the ground. In this model, parameter tree density determines the number of trees per hectare, which can be adjusted at the beginning of simulation. Orangutans in the model will move depending on the tree type and the support that is available.

In addition to the proportion of locomotor modes in orangutan movement, the total daily travel length can also be calculated from the model simulation. According to Morrogh-Bernard in her dissertation (Morrogh-Bernard, 2009), the daily travel length of orangutan could reach 1 km per day. In the model, the travel length can be calculating by summing up the straight lines between trees that are visited during the day. This would make sense because the scale of the model is one meter square per grid cell so that it would give similar numbers. Orangutans in the model are assumed to move in straight lines, which might not represent the reality. However, in the reality, the daily travel length is measured from gps points. Therefore, these two patterns are easily comparable and compatible to each other.

The energy expenditure of orangutans also varies based on the level of disturbance to the forest. This is because of the deficit in fruit availability combined with the higher energy required to do work. This is confirmed in a study carried out by Harrison and colleagues (Harrison et al., 2010). They reported that the energy expenditure of orangutans were having energy deficiency in period with less fruiting tree, compared to the fruiting season. Please check this measurement again for the energy budget.

In addition, orangutan home range size is also a pattern that can be measured from the field. homerange are measured by marking the location which the animal is found. In the model, this is also possible to do, by recording the location of trees that the orangutans visited over the course of time. However, to get to the home range, the time scale in the model would need to be increased until at least one year.

1. **Entities, State variables, scales**

Orangutan and trees are the main entities in the model. Link is an entity which is dependant on the state of tree agents. Links are described in the model as a virtual connection between trees. Links are established to assist orangutan agent in their movement decisions. Information that is contained by the links include the distance between trees and the support-type. Support-type defines which locomotor behaviour an orangutan can perform to reach a tree at the other end of the link. It can be sway, brachiate, or climb/walk. The description of each entities in the model are shown in Table 1.

Table 1. List of entities and state variables

|  |  |  |  |
| --- | --- | --- | --- |
| **Entities** | **State Variable** | **Values and Units** | **References** |
| Orangutan | Body-mass | 38 – 100 kg | (Harrison et al., 2010) |
|  | Arm-length | 0,5 – 1 m | (Oishi et al., 2009) |
| Tree | Height | 1 – 5 m |  |
|  | Crown-width | 15 – 40 m |  |
|  | Fruit availability | 10 – 40 cm |  |
| Link | Distance | 1 – 10 m |  |
|  | Support-type | Sway / brachiation |  |

To represent the describes setting, the concept of network is used which includes trees as nodes with links in between. The orangutan is represented as an agent which position is on a node and can move along nodes which are connected to each other. The spatial size of simulation is 1 Ha, represented in the model as 100 x 100 grid cells sized 1 square-meter each.

The model represent 20% of orangutan day-time which equals to 144 minutes. One time-step in the model represent one second. Therefore the total simulation length in the model equals to 8640 time-steps in NetLogo.

1. **Process overview and scheduling**

At every timestep, the model checks whether the orangutan is hungry. If orangutan is hungry, then it will go to a fruiting tree. Otherwise, it will select a random non-fruiting tree.

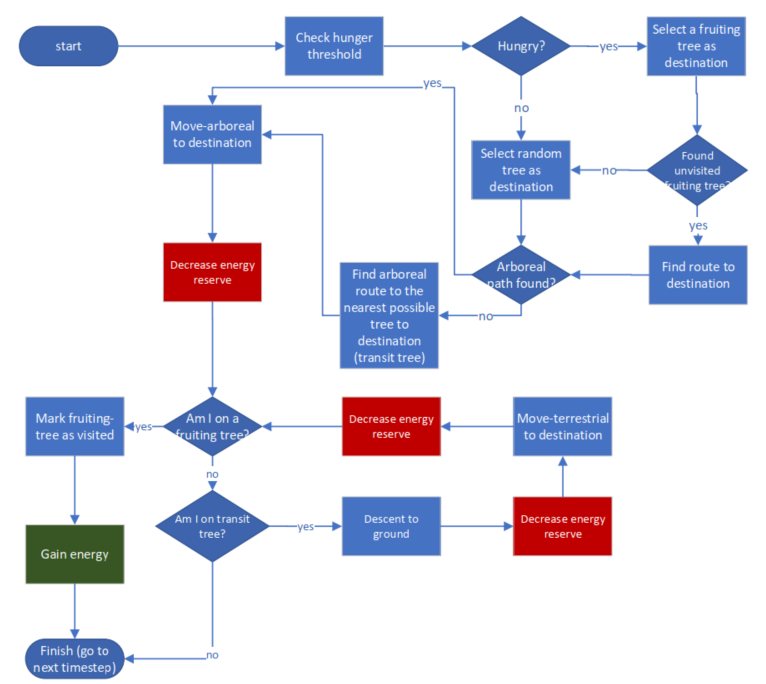


Fig. 1. Flowchart diagram illustrating the process in one timestep in the model

Input Data:

Tree inventory data from BNF, the map spatial data raster map from satellite

For the input data, the tree inventory data is obtained from the study area in sebangau, central Kalimantan.

Harrison, M. E., Morrogh-Bernard, H. C., & Chivers, D. J. (2010). Orangutan energetics and the influence of fruit Availability in the nonmasting peat-swamp forest of sabangau, indonesian borneo. *International Journal of Primatology*, *31*(4), 585-607. <https://doi.org/10.1007/s10764-010-9415-5>

Manduell, K. L. (2012). Habitat variation and its influence on the locomotor ecology of wild orangs. *Thesis*(September).

Manduell, K. L., Harrison, M. E., & Thorpe, S. K. S. (2012). Forest Structure and Support Availability Influence Orangutan Locomotion in Sumatra and Borneo. *American Journal of Primatology*, *74*(12), 1128-1142. <https://doi.org/10.1002/ajp.22072>

Morrogh-Bernard, H. (2009). *Orang-utan Behavioural Ecology in The Sabangau Peat-swamp Forest, Borneo* University of Cambridge]. Cambridge.

Oishi, M., Ogihara, N., Endo, H., Ichihara, N., & Asari, M. (2009). Dimensions of forelimb muscles in orangutans and chimpanzees. *Journal of Anatomy*, *215*(4), 373-382. <https://doi.org/10.1111/j.1469-7580.2009.01125.x>