Bee movement in the environment model manual

Description:

Model of movement of bees in the environment, created from spatial data (elevation, land cover...).

This model describes the way bees explore the surroundings of selected origin point, when looking for food sources based on spatial data.

Model can also be used to test possibility of American foulbrood (AFB) infection of bees through robbing in specified locations

This model requires GAMA Platform software version 1.8 (https://gama-platform.github.io/download)

Computation time takes 20 – 30 minutes (may take about 50 min on low-end PCs)

The input files have been created and visualization of the results was performed in ArcGIS Desktop. (For user-own input files and visualization, ArcGIS desktop of similar software is required)

The downloaded file (Bee-movement-in-the-environment-model--master.zip) should be placed in gama_workspace folder and extracted

The zip archive (project.zip) should be extracted as well to get .project file

1) **Data preparation (input files – GIS software)**

a) Image files (PNG) (Examples provided in the downloaded folder (images))
Default size of input file is 200 x 200 pixels with resolution of 70 m.

Elevation or land cover raster data with black to white color ramp (black for lowest values and white for highest values of resistance for movement)

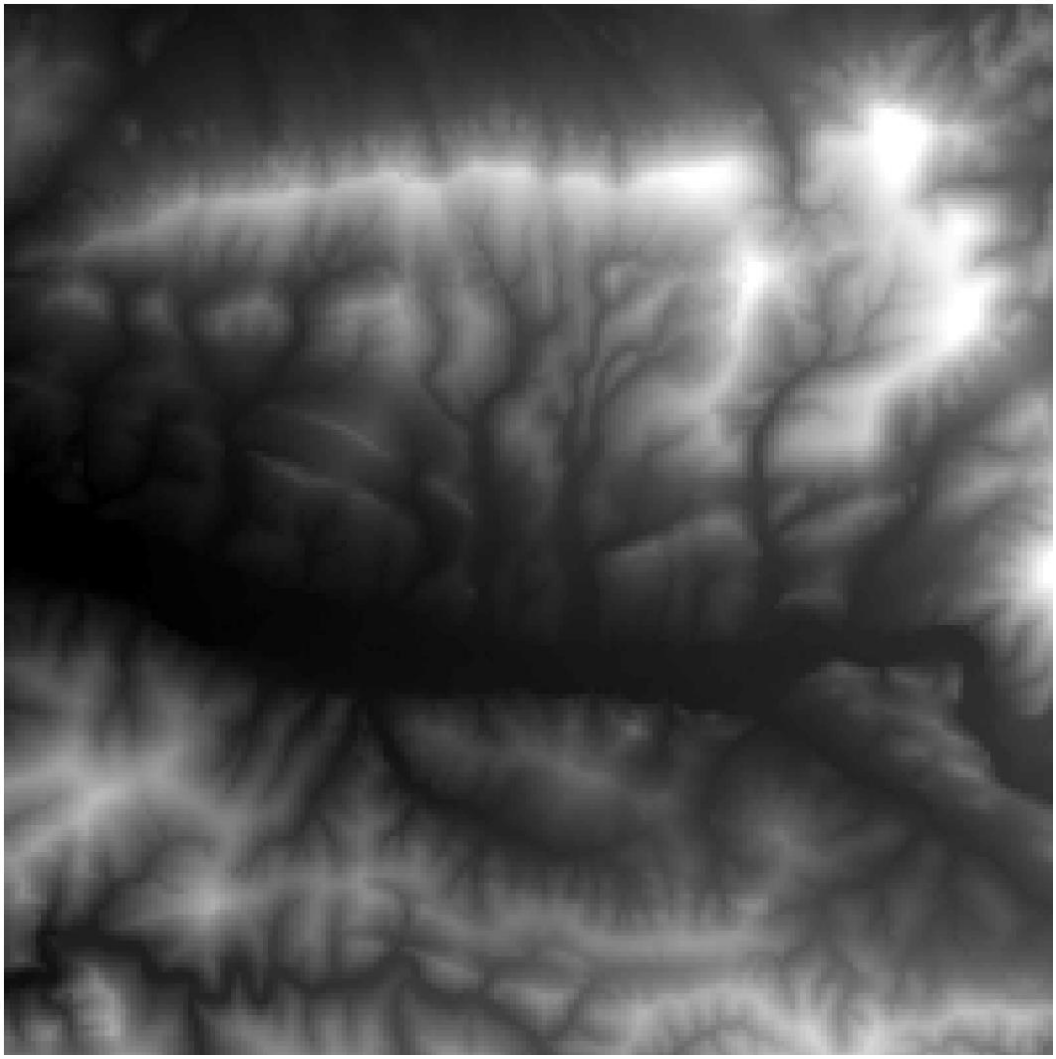
Elevation data can be used directly after resample
Land cover (LC) data can be classified according to table below (or user own classification of LC with resistance values can be created)

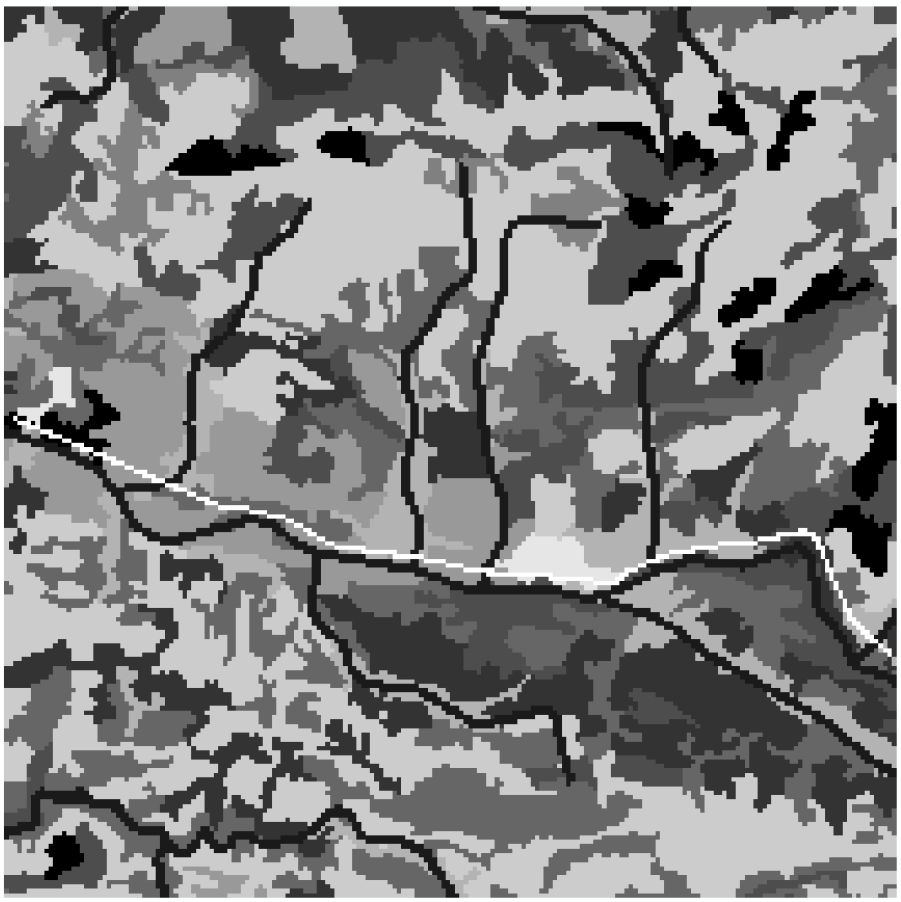
Category	**CORINE CODE**	**Resistence**
Broad-leaved forests	311	1
Water bodies, rivers + (buffer 70 m)	ArcČR 500	10
Pastures and meadows	231	25
Mixed forests	313	30
Land principally occupied by agriculture, with significant areas of natural vegetation	243	35
Transitional woodland/shrub	324	40
Agricultural areas	211, 242	50
Discontinuous urban fabric, Green urban areas	112, 141	60
Coniferous forests	312	65

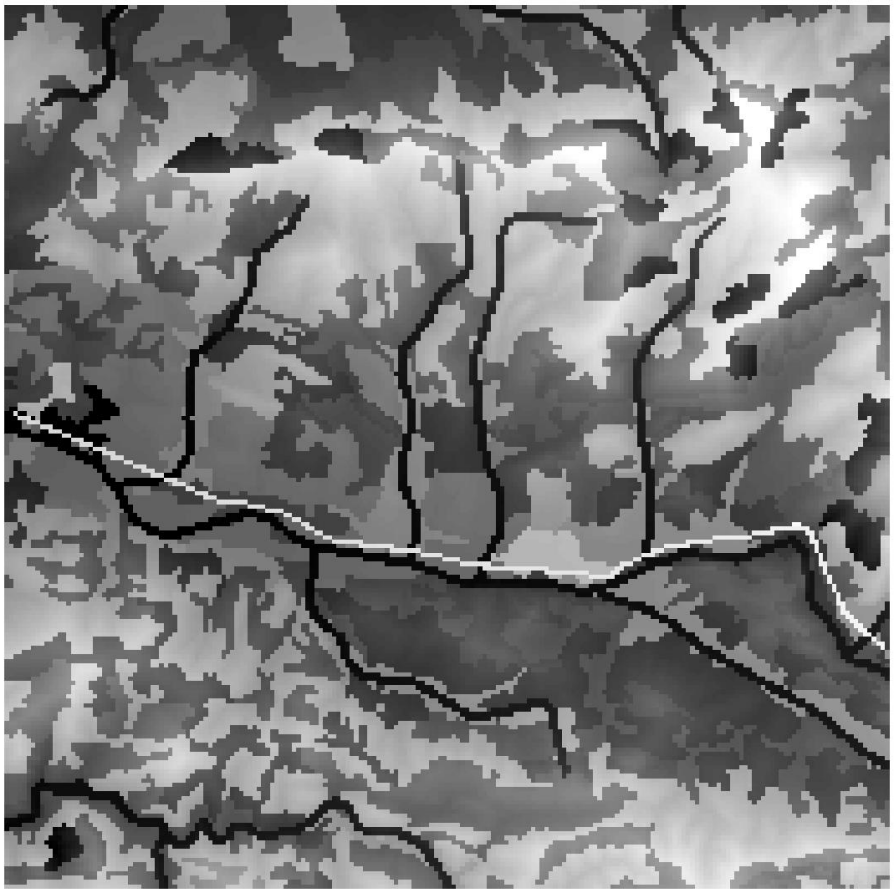
Industrial or commercial units, Mineral extraction sites	121, 131	80
Main Roads + (buffer 35 m) Highways + (buffer 70 m)	ArcČR 500	100

The input rasters may be combined using raster calulator (after the values of elevation are divided by 10 so both data files have approximately same weight)

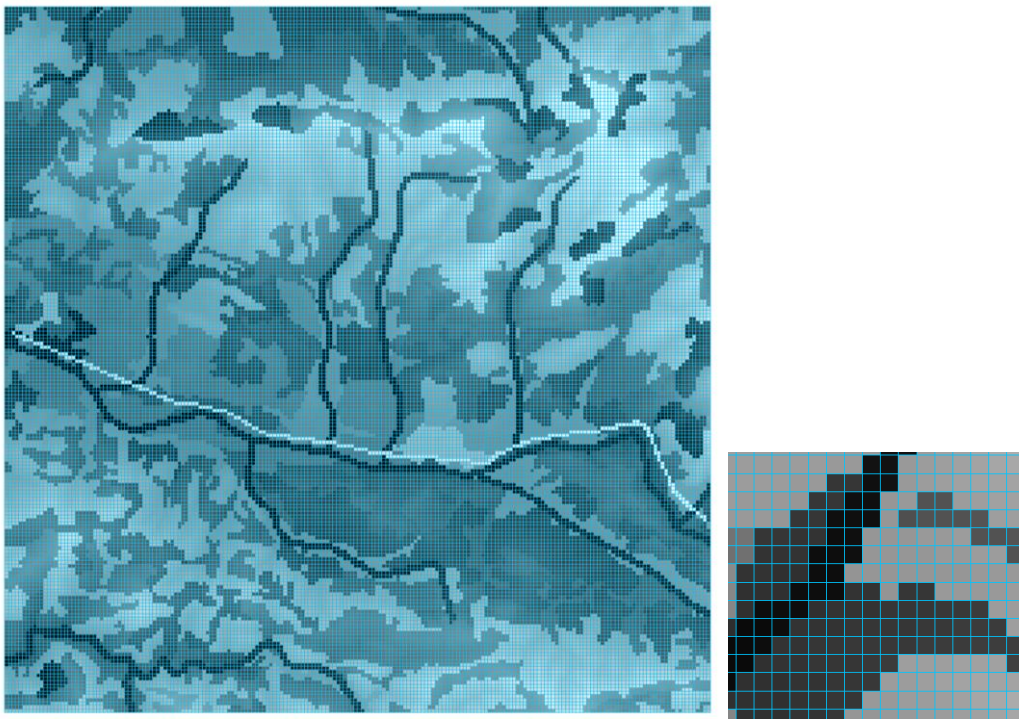
The input files should look similar to examples below
(Elevation, Land Cover, combination)







b) Vector based grid (fishnet) polygon (to save results in ArcGIS Desktop or similar software) and line (model input file). With same parameters as image data files (200 x 200 sectors with size of 70 m). The layers should be perfectly aligned. The file itself should be placed into includes folder of the project



2) Model GAMA Platform

a) Model with examples files is imported through User Models -> Import GAMA Project and browse and select downloaded folder

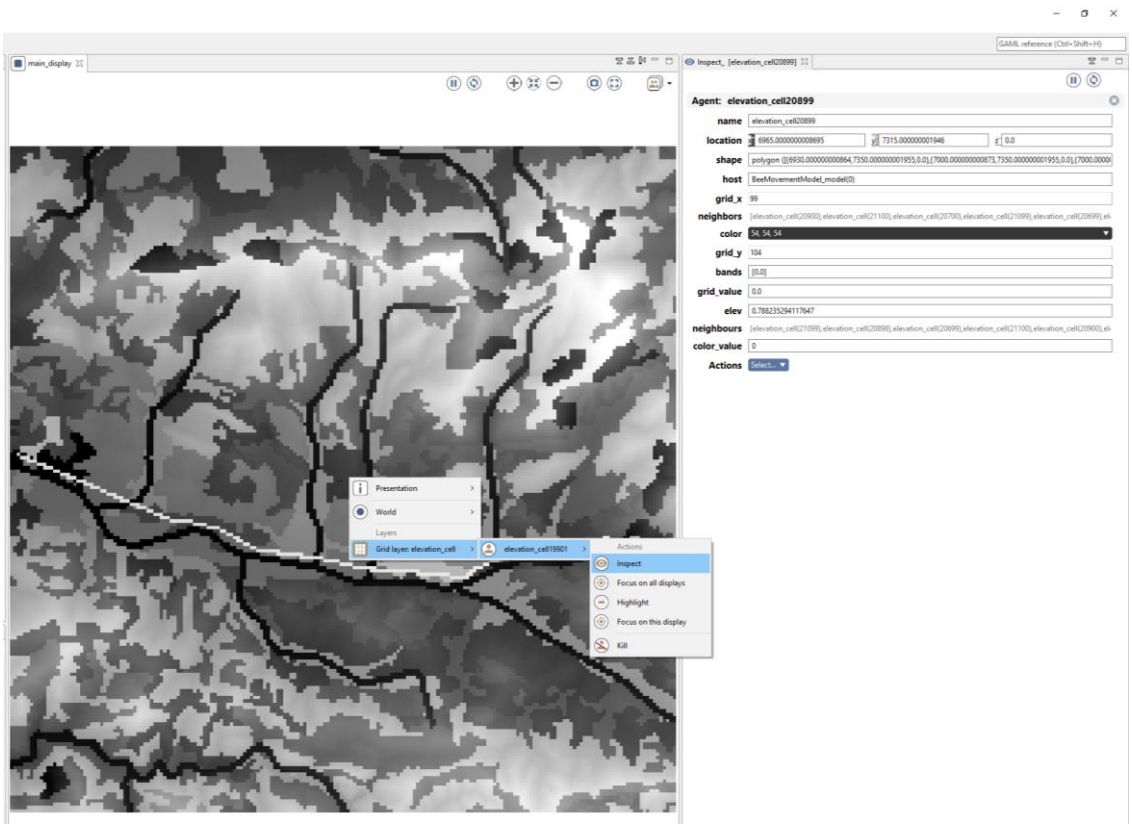
b) Names and location of input files

```
/* Spatial data location for inicialization ( Raster image file and shapefile vector grid  */
    file map_init <- image_file("../images/ElevLandCover.png");
    file shape_file_grid1 <- file("../includes/Grid70l.shp");
    geometry shape <- envelope(shape_file_grid1);
```

c) Location of hives (based on real location… To get model values -> Run the model(simulation perspective opens) Find the location in the model space, right click on the cell and follow procedure showed below. Then copy cords from location attribute and change them in the code

d) Infected hives are added through the same procedure as in C)… Change color_value attribute of cells with infected hives from zero to one

e) Size of modelled environment 200 x 200 by default same as the size of input file




```
37      create species:hive number:1 with:(location:{6895.000000001834,7035.000000001872});
38      create species:hive1 number:1 with:(location:{6825.000000001816,7035.000000001872});
39      create species:hive2 number:1 with:(location:{6965.000000001854,7035.000000001872});
40      matrix init_data <- map_init as_matrix {200,200};
```

f) Maximum distance for bee is set to 7 km (100 cycles of 70 m cells), This can be changed: either through number of cycles or if the size of the cell is different
Result are saved as shapefile to folder results/ElevCor/ and name of the file. The number at the end of the name of the file should be changed before running the experiment. Otherwise result may be rewritten

```
51  /* Save explored cells to shapefile after maximum distance of bee movement is reached( 100 cycles x 70 m cell size = 7 km)  */
52  /* Save folder location and name of the output file (Name of the file needs to be changed for each iteration  */
53  reflex save_color_value when: cycle = 100{
54  save elevation_cell to:"../results/ElevCor/ElevLC1.shp" type:"shp" with:[color_value::"Visited"];
55  }
```

```
/*Simulation pauses after after maximum distance of bee movement is reached  */
reflex stop_simulation when: (cycle = 100) {
        do pause;
    }
```

g) Initial location of bee each bee type (3x) . Values can be found in the simulation perspective. Same procedure as in C) attributes grid_x and grid_y

```
125  /* Initial location (cell's grid x a y values) */
126      elevation_cell myCell<- elevation_cell grid_at {98,100}  ;
127
```

```
208  /* Initial location (cell's grid x a y values) */
209       elevation_cell myCell<- elevation_cell grid_at {97,100}  ;
290  /* Initial location (cell's grid x a y values) */
291       elevation_cell myCell<- elevation_cell grid_at {99,100}  ;
```

h) Bee movement behaviour. By default there is 20 % probability that bee chooses cell with higher resistance value. This can be changed under (if flip (0.20)) for each type of bee

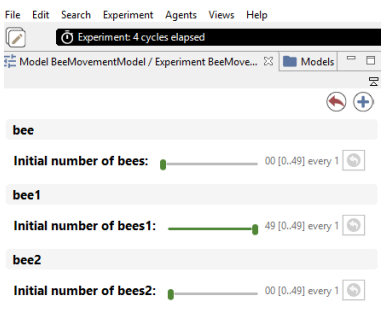
```
169  /*Momevent of agent based on values of cells */
170
171  /*Probability of choosing neigbour with higher resistence values (20 % by deafult) */
172  /*Cretion of list of neigbours with higher resistence values with exlusion of already visited cells */
173  /*Bee moves to one of cells from the list if not empy, otherwise one of neigbours is chosen instead */
174      elevation_cell choose_cell {
175          if flip (0.20) {
176              list<elevation_cell> Cell_up <-(myCell.neighbours) where (each.elev <= myCell.elev and each.color_value != 2 );
177              if not (empty (Cell_up)){
178              return one_of (Cell_up);
179              }
180              else{
181              return one_of (myCell.neighbours);
182                  }
183
184  /*Cretion of list of neigbours with lower resistence values with exlusion of already visited cells */
185  /*Bee moves to one of cells from the list if not empy, otherwise one of neigbours is chosen instead */
186          }else {
187          list<elevation_cell> Cell_down <-(myCell.neighbours) where (each.elev >= myCell.elev and each.color_value != 2 ) ;
188              if not (empty (Cell_down)){
189              return one_of (Cell_down);
190              }
191              else{
192              return one_of (myCell.neighbours);
193              }
194       }
195     }
257      elevation_cell choose_cell {
258          if flip (0.20) {
339      elevation_cell choose_cell {
340          if flip (0.20) {
```

i) Creation of modelled environment with list of neighbours for movement and interaction

```
367  /*parameterers of grid and creation of list of elevation cells based on their real values. Width and height must correspond with input file  (line 40 of the code) */
368  /*cration of list of neighbours for movement and interaction (8 closest by default) */
369 grid elevation_cell width: 200 height: 200 neighbors:8 {
370  float elev <- 1 - (((color as list)[0])/255);
371  list<elevation_cell> neighbours <- self neighbors_at 1 ;
```

j) The number of bees can be changed in the code or through sliders in the simulation perspective (in this case experiment should be reloaded CTR +R) . Total number of bees should not exceed 49 (with the default resolution and size of modelled space) due to computation time.

```
18 global {
19      int nb_bees_init <- 15;
20      int nb_bees_init1 <- 17;
21      int nb_bees_init2 <- 17;
```



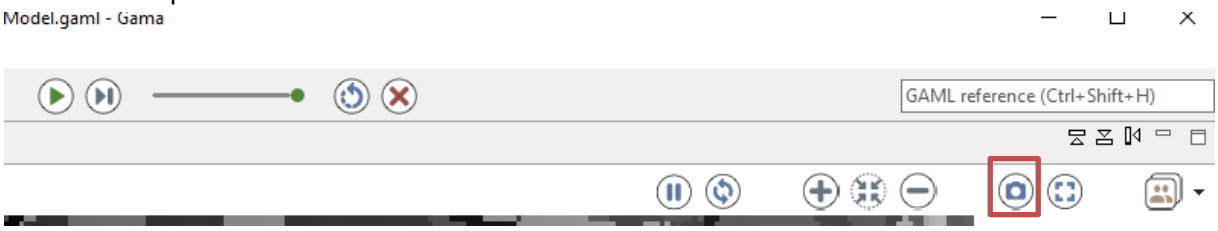
If the number of bees is changed the following conditions should be adjusted to correspond with the number of bees in the simulation

```
/*Pause simulation when bee reaches infected hive, condition needs to be changed based on the number of initializatied bees (new bee is created to pause the simulation) */
reflex pause_simulation when: (nb_bee > 15) {
        do pause;
    }

reflex pause_simulation1 when: (nb_bee1 > 17) {
        do pause;
    }

reflex pause_simulation2 when: (nb_bee2 > 17) {
        do pause;
```

k) After the simulation ends a Snapshot with explored area may be created. The image is saved as PNG file under gama_workspace -> Bee movement in the environment Model -> models -> snapshots



Or procedure using the created shapefile may be used instead to visualize and save all results in one file in GIS software as described below

The simulation should be run repeatedly (25 iterations were performed in the test experiment). After each iteration a snapshot can be taken or shapefile with result can be used (with number for each iteration e.g ElevLC1.shp, ElevLC2.shp…)

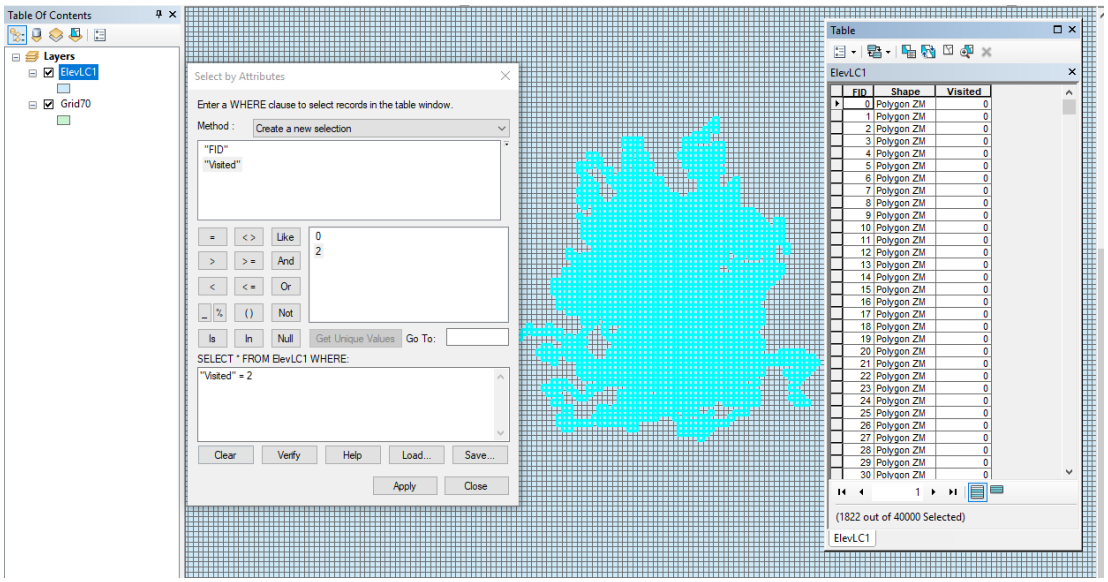
3) Visualization and storage of data in GIS software

a) The results of the model in shapefile format can be found in gama_workspace -> Bee movement in the environment Model -> results -> ElevCor -> name of the file

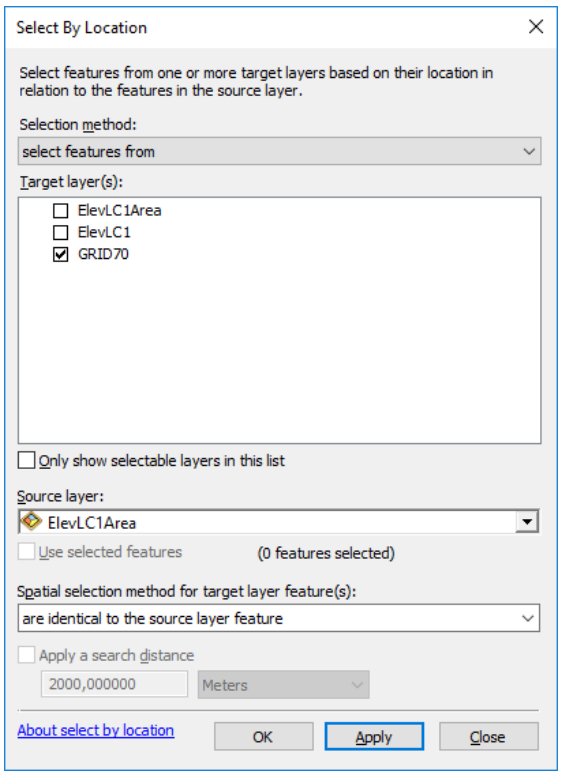
```
reflex save_color_value when: cycle = 100{
  save elevation_cell to:"../results/ElevCor/ElevLC1.shp" type:"shp" with:[color_value::"Visited"];
 }
```

b) The results should be loaded into the GIS software together with the polygon fishnet created in 1b) (shapefile GRID70 in includes folder is provided as example)

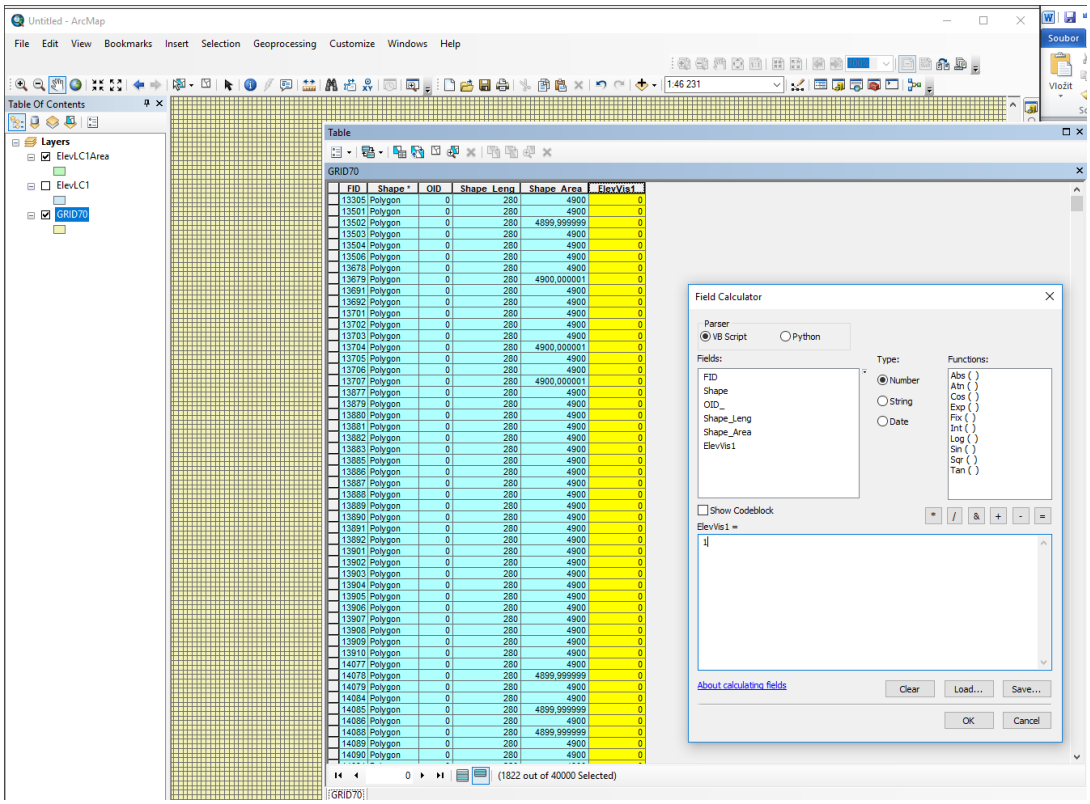
c) Next visited sectors are selected as shown below and new layer may be created



e)Next sectors from the polygon fishnet are selected as shown in the condition below



f)New field is added and with value 1 for the selected sectors



g) Steps 3b) to 3f) are repeated for each result. Finally all saved results (25 columns with ones and zeros) are counted, divided by number of results and multiplied by 100 to get percentage of intensity of visits per sector. The final result can look similar to the one shown below

Green color shows the intensity of visits of sectors.
Red are infected hives

In this example the bees will not be infected from AFB + hives localized in Veřovice. Though they may infect themselves through robbing in Vidče (low probability). Highest probability of infection is in the dark green sectors in Zubří