Model description

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This model was programmed for a class project, which studied the effects of urban sprawl on avian distribution. For the urban sprawl part of the model, we started from the model in (Sudhira, 2004). But in fact we did not exactly replicate Sudhira's model.

Purpose

The purpose of this model is to study how the urban sprawl in radial direction from one or several urban centers influences the bird distribution both inside and outside the urban area.

State variables and scales

This model contains four types of agents: birds, builtup (buildings), land (naturally suitable places for birds to live in) and greenbelt (urban greenbelt). Urbanized area includes all the patches with a distance less than or equal to a certain value to any land agent, and other patches are rural area. In each time step, each bird moves to the patch with the largest utility to itself in its vision. The world is represented by a 51 by 51 cell space.

Process overview and scheduling

In each time step, the program will proceed by following the actions below:

1) Calculate the energy that can be offered by each patch to each bird located therein.
2) A new bird is reproduced with a certain probability when an existing bird's energy gets to a certain level.
3) Each bird moves to the patch with the largest utility in its vision.
4) Each bird will die if its energy is below or equal to 0
5) Each bird will die with a certain probability even when its energy is above 0
6) If the number of birds in one patch is above the maximum level, a bird with the least energy will die until the number of birds is exactly the maximum number.
7) Birds lose energy due to metabolism and also get energy from the patches where they stay.
8) If there are not half of the patches to be urban, steps (i)-(iv) are implemented.
   (i) Greenbelt agents are created with a certain probability in urban patches where there is no builtup agent or other greenbelt agents. And the land agent in the patches where a greenbelt agent is created disappears.
   (ii) New built-up agents are reproduced from existing ones with a certain probability and are located in the neighboring patch relative to their parents.
   (iii) If the number of builtup agents in the patch where a new reproduced builtup agent was created has get to a certain level or there is already a greenbelt agent there, the builtup agent will move to look for another patch to stay.
   (iv) All the patches with a distance less than or equal to a certain value to any land agent are

urbanized.

Design concepts

Emergence. Urban sprawl emerges from the reproduction of builtup agents and the disappearance of land agents. Bird amount and distribution are influenced by the initial setting of land agents and the urban sprawl pattern.

Interaction. Builtup agents interact directly with each other and with land agents and greenbelt agents at the same place. Bird agents interact directly with each other and other three types of agents.

Adaptation. Builtup agents adjust their position according to the constraint of the number of builtup agents that can stay at the same patches and existence of greenbelt agents. Bird agents that are adapted to their environment will survive, and those that do not fit into the environment will just die.

Stochasticity. The growth rate of builtup agents is in fact used to be the probability of a builtup agent to reproduce. Greenbelt agents are also created in the urban patches without land agents with a certain probability. Initialization of the agents and the move of builtup agents are both at random. There are probabilities of birth and death for birds to control their birth and death rates.

Initialization

Several variables in this model should be initialized: the number of cities, the radius that is used to define the urban area around the builtup agents, the initial percent of land agents in the plane, the initial percent of builtup agents, the growth rate of builtup agents, the number of builtup agents that can stay in one patch, the probability to create greenbelt agents, the initial percent of bird agents, the birth probability of birds, the death probability of birds, and the number of birds that can live in the same patch.

Input

Range of possible parameter values are listed below using the style of [x y z], where x, y, z are possible values, or [a, b, c], where a and c denote the minimum and maximum values respectively, and b is the step of increase.

number-city (the number of cities): [1 2 4]
radius (the radius to calculate urban patches): [0, 1, 3]
initial-percent-land (the initial percent of land agents): [1%, 1%, 50%]
initial-percent-builtup (the initial percent of builtup agents): [1%, 1%, 20%]
builtup-growth-rate (the growth rate of builtup agents): [1%, 1%, 50%]
number-builtup-per-patch (the maximum number of builtup agents that can stay in one patch): [1, 1, 10]
greenbelt-growth-probability (the probability to create greenbelt agents): [1, 0.5, 20]
initial-percent-bird (the initial percent of bird agents): [0, 1, 50]
birth-probability (the birth probability of birds): [0, 1, 100]

death-probability (the death probability of birds): [0, 1, 50]
number-birds-per-patch (the maximum number of birds that can live in the same patch): [1, 1, 20]

Submodels

The model in fact includes two parts: one is the urban sprawl part, and the other is for the bird.

Urban sprawl part

The initial number of land agents initial-number-land is defined by the initial percent of land agents initial-percent-land and the total number of patches defined in the model:
initial-number-land = initial-percent-land * world-width * world-height,
The initialized land agents are distributed at random in the plane, and any two initialized land agents do not occupy the same patch.

The builtup agents are initialized and distributed as near as possible to the city center(s). But if there are already any land agents located there, the initialized builtup agents will move away. The initial number of builtup agents, initial-number-builtup, is defined as:
initial-number-builtup = initial-percent-builtup * world-width * world-height.

Each patch in the plane is defined to have an internal variable of city?, which denotes whether this patch is in the urban area. All the patches that have a distance from one builtup agent less than or equal to radius are initialized to be urban patches, and others are not.

After the initialization process, the urban growth proceeds with the increase of the number of greenbelt agents and the number of builtup agents. Land agents in the urban patches will disappear increasingly. And each builtup agent has a probability of builtup-growth-rate to reproduce a new builtup agent, which may move away from its birth patch to another neighbor patch. The constraint of number-builtup-per-patch also applies here.

The urban sprawl will stop when 1/2 of the patches in the plane belong to urban area.

Bird part

Bird agents will reproduce with a probability of birth-probability if their energy level is equal to or more than 12 units. A new bird and its parent have the same energy as half of the original energy of the parent. The reproduced bird does not inherit the same city-preference level as that of the parent, but has a little change.

Different patches can offer different energy to the birds. Each patch with a land agent or greenbelt agent in it can offer 3 units of energy to each bird that stay therein. The energy that each urban patch without any land agent and greenbelt agent therein can offer to each bird in it is calculated by using the following formula:
(1 – number of builtup agents here / number-builtup-per-patch) * 2 + 1
Each rural patch without any land agent therein can offer 0.1 unit of energy to each bird in it.

Each bird agent has a preference for urban area (preference-for-urban) and a preference for rural area (preference-for-urban) that satisfy

preference-for-urban + preference-for-urban = 1.
In each time step, each bird will move to the patch with the maximum utility in its vision. The utility of the patch to a bird is defined as:
utility = preference * energy offer from the patch.

The bird agents with an energy level above 0 have a probability of death-probability to die. And the living bird agents lose energy due to metabolism and get energy from the patch where it stays.

Implementation

The model is implemented in NetLogo 4.0.3. Figure 1 is a model result by using a set of parameter of (number-city = 1, radius = 1, initial-percent-land = 25(%), builtup-growth-rate = 10(%), initial-percent-builtup = 1(%), number-builtup-per-patch = 5, greenbelt-growth-probability = 10(%), birth-probability = 85(%), death-probability = 5(%), initial-percent-bird = 5(%), number-birds-per-patch = 5).

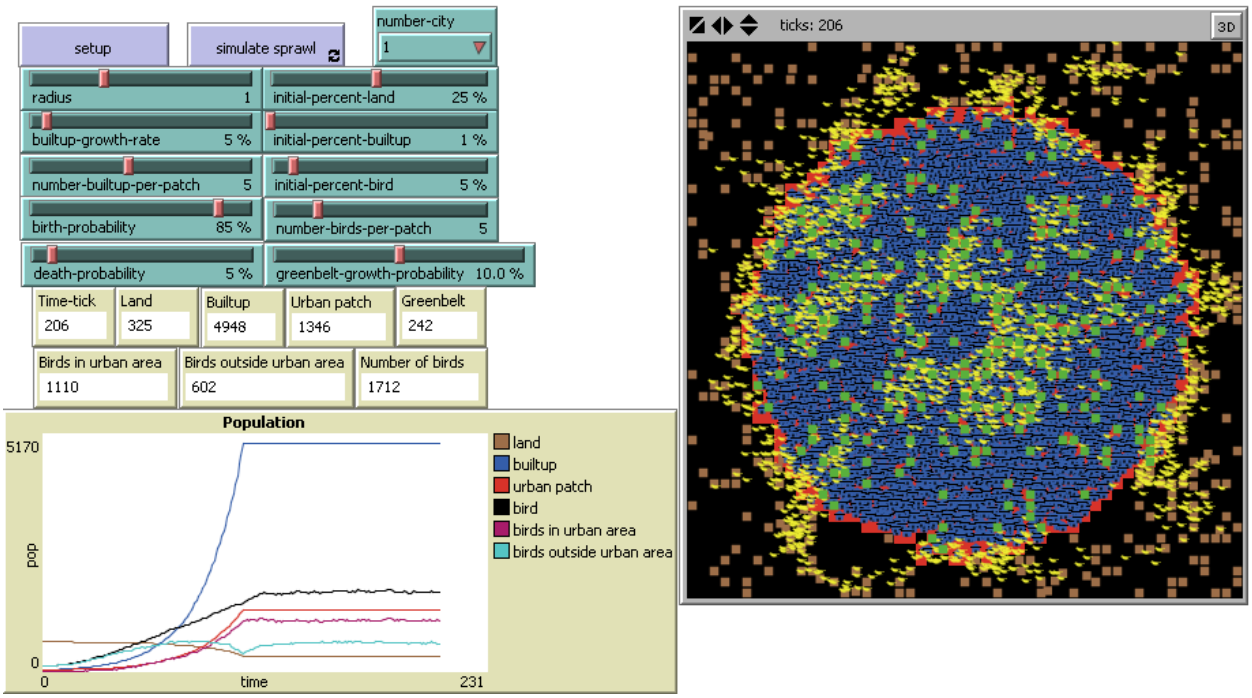

Figure 1. Model result example

References

Sudhira, H. S. 2004. Integration of agent-based and cellular automata models for simulating urban sprawl. Master thesis. International Institute for Geo-information Science and Earth Observation, Enschede, The Netherlands.