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AN EXTENSION TO WOLF SHEEP PREDATION (DOCKED HYBRID) AGENT-BASED MODEL IN NETLOGO

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ABSTRACT

In old Wolf Sheep Predator and Prey model a relationship among two different types of models is shown in a relatively natural ecosystem using NetLogo. One of these is a simple mobile agent-based model for simulation while other is an aggregate model. Evaluation of both the models can be done in one by one manner or by using parallel comparison button to see behavior of both the models for the same inputs. Agent based model also captures very basics of the reality to make simulation. In this model, a random procedure is used to simulate wandering of predator (Wolves) and Prey (Sheep) in specified area. A fixed gain in energy is awarded to the Wolf on each interaction with Prey while each step on which this type of interaction is not taking place, causes a constant decrease in energy. Thus, for wolves to survive it is necessary to eat sheep to regain their energies otherwise they will start dying due to lack of energy. This construct has an assumption that reproduce rate or birth rates of wolves and sheep have a constant probability and is proportional to the population of both species. Aggregate model is a construct that is modelled using system dynamics and only consists of standard LotkaVolterra equations of predator and prey. But our new extension to this old model introduced a third agent property Food (Grass) as a competitor to make it more realistic. Now the interaction of these agents has introduced more complexity in the model and also altered the equilibrium parameters. When sheep encounters a cell with grass it eats it only if his energy is not reached to its maximum limit. Each grassy cell adds in energy of the sheep. Model initially have the assumption that probability of reproduction time of grass at each cell is constant. After, we also have introduced a new docked model for comparison between newly created Wolf-Sheep agent based model and chained aggregated model. The comparison shown that for all equilibrium states actual Wolves in agent-based model are 3 times lesser than in system dynamics aggregated model.

Keywords: predator-prey interactions; aggregated predator-prey model; agent-based predator-prey model; NetLogo; docked hybrid simulation comparisons; system dynamics;

1. INTRODUCTION

Predator and prey constructs provide the fundamentals to capture the life and natural environments that are strongly influenced by predation phenomenon. These model exhibits the possibilities when and how prey and a predator interaction take place and how it effects the overall ecosystem. These models elaborate how the stronger species (i.e. predator) causes increase and decrease in the quantity and unusual scattering of the weaker species (i.e. Prey). Sometime these models are said to be the true representatives of the theory “survival for the fittest” [1].

To be alive, the stronger species have to do predation on weaker species, which may cause logical or sometime universal extinction of the species that have no way to make themselves safe from predator species. In tussle to achieve a secure environment, the weaker species have to do continuous migrations for one place to another and fear of life always rests there for weaker species. Shortly, collision between these two species (i.e. predator and prey) is like a win-loss interaction [2]. In other words, this interaction causes success for one specie while defeat for other (i.e. death for one and life for other).

In current environment situations in Pakistan, some species are at the very end of their existence. They may be a prey or a predator. For example, Snow leopard has a Possible habitat not less than 81,000 square kilometers in HinduKush and KaraKorum mountain ranges. In this wide area, total number of animal count for snow leopard is only 400 to 450 approximately [3]. Most of the population is concentrated in the higher reaches of the Gilgit and Baltistan [4]. There is a danger of extinction this animal. Population growth of this animal is strongly

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dependent on the availability of the prey in its habitat and growth rate of its prey strongly depends on availability of the food. So, it's very important to take food growth into account so that rational decisions can be drawn to control Population of Predator and Prey.

1.1 Classic Lotka Volterra construct

Lotka Volterra equations are an important construct to represent the predator and prey model in natural eco-system [5]. This construct assumes that if A, B, C and D are real positive constants where 'A' is Natural Growth rate of the prey, 'B' is

Rate at which prey is destroyed by predator, 'C' is Natural rate of death of the predators and 'D' is Rate of increase in predator population after eating prey, then following condition holds:

If prey population is 'x' then it increases with a rate of 'A' times the total population of the prey and at the same time a decay in the population can be seemed by a rate 'B' times 'x' times 'number of predators'. This means decrease in prey's population is proportional to the predators and prey population.

Let's say 'y' is the stock variable for the predator population, then decrease in 'y' over time is directly proportional to the 'y' times 'C' and increase in 'y' over the time is 'D' times 'x*y'.

Coupled D. E's generated by above systems are following:

$$\frac{d_x}{d_t} = Ax - Bxy \qquad \text{(I)}$$

$$\frac{d_y}{d_t} = -Cy + Dxy \qquad \text{(II)}$$

At dx/dt =dy/dt = 0 critical point occurs hence (I) and (II)

becomes A - By = 0 and -C + Dx = 0

The one and only still point is thus situated at (x ,y) = (C/D ,A/B).

1.2 A Simplified Three-Species Model

Now suppose that the extension to the simple predation model with two species is a new model with three species. The food chain of this new model is as one is at top of the food chain second is in the middle and third one is at bottom. Let x, y and z be denoting species in bottom up order then following differential equations models their behavior: dx/dt= Ax - Bxy

dy/dt= -Cy + Dxy - Eyz

dz/dt= -Fz + Gyz

where A, B, C, E, F and G are real positives representing rates as in Lotka Volterra General Equations.

Same as in classic predation construct, in this model: x has a reproduction rate A times total population (i.e. 'x') while –Cy and –Fz are natural rate of death for y and z respectively. Similarly, Dxy and Gyz is a gain in population of y and z respectively due to eating prey and results in decrease of –Bxy and –Eyz in population of the hunted prey. Interestingly, to avoid the inconsistency in the model, the author of the model has given 'y' a natural death rate instead of rate of growth in absence of the predator 'z'. This handles the exception when at a certain point if 'x' goes extinct, then if the case was positive growth rate instead of natural death then still an increase in the population of the 'y' could be seen although prey: - 'the source of the food' had switched off. The generalization of this three species construct is also very restricted that it although allow to add third specie in the old LotkaVoltera Model but imposes a condition that specie at the top can only hunt middle one in the food chain and lower one can only be hunted by a specie at middle level of the food cycle. This implies in the scenarios where specie at the top does not eats the species at the bottom directly. This model can't abstract the environments where both 'z' and 'y' can hunt 'x'.

A generalized Three-Species Model [5] Devireddy proposed a generalized three-species model that allows for any number of the species to be the prey or predator (or both). His extension allows the existence of mutual Symbiosis which is a phenomenon where two species benefits from coexisting in the same environment.

Our model is agent-based model that implements the simplified three-species model in NetLogo by exploiting two species Wolves-Sheep model which available in the library of NetLogo.

2. RESEARCH METHODOLOGY

We have used Agent based Spatial Modelling to extend previously available model and System Dynamics to introduce Food as a stock variable in aggregated model. We used NetLogo for Spatial Agent based modelling and System Dynamics Modeler for aggregated model [6-9]. New model is applicable in scenarios where predator eats prey and prey's food is not a mobile agent and predator is not interested in prey's food.

Our model has the following Assumptions:

i. Prey population is totally responsible for an increase or a decrease in food supply. That is if prey population increases food availability per unit prey decreases.

ii. There exists a chain such that predator(wolves) eats only prey(Sheep) not the food(grass).

iii. Food always grows with same growth rate without seasonal Environmental and other conditional effects.

iv. Predators have limitless appetite. So they will eat sheep at each contact in a cell.

v. Predator growth rate and prey reproduction rate are directly proportional to their current population.

vi. Movement of sheep is biased towards the Grassy spatial locations.

vii. Natural death rate of Sheep is neglected as when a sheep dies, it becomes a prey of wolves. So it is covered in predation rate of wolves on sheep.

2.1 Addition of Grass in agent-based model

In agent-based model we added a following to add third agent grass as a property of the cell as following:

a. Grass reproduction mechanism

```
if pcolor = brown [

  if random 100 > (100 - (grass-growth-probability * 100) )            [

    set pcolor green

   ] ]
```

b. Grass predation mechanism to eat-grass

```
if pcolor = green [

    set pcolor brown

    set energy energy + gain-after-eating-grass

] End
```

c. Updates in move-sheep procedure

We added the concept of energy consumption at each step as each step in search of the food consumes for units of energy.

d. Extension in previous system dynamics model

For the sake of the comparison, we have also extended the system dynamics model to make it more realistic abstraction of reality. Equations of the system dynamics model are:

$$\frac{dG}{dt} = \alpha G\left(1 - \frac{G}{1089}\right) - \gamma SG$$

$$\frac{dS}{dt} = \beta(\gamma SG) - \rho SW$$

$$\frac{dW}{dt} = \sigma(\rho SW) - \delta W$$

Here ‘G’, ‘S’ and ‘W’ are ‘Grass’, ‘Sheep’ and ‘Wolves’ respectively. Here α is Grass Growth rate and γ is Grass eaten rate. While β, ρ, σ and δ are Sheep birth rate, Wolves predation rate, wolf Birth rate and Wolves natural death rate respectively. All rates are real positive and are shown in Figure 1.

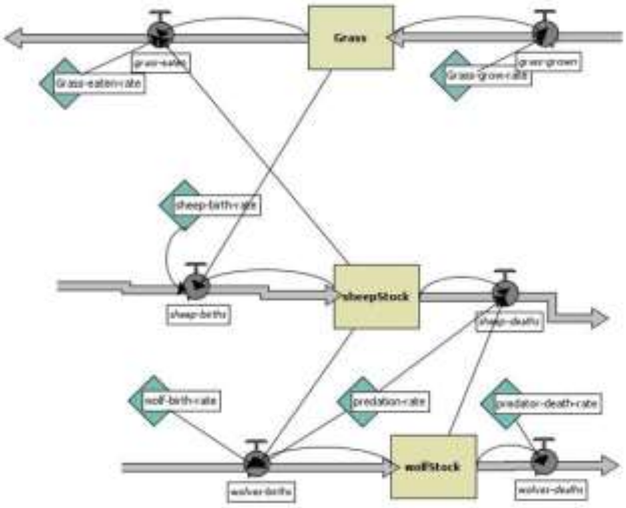

Figure. 1 Real positive rate

After various simulations of the model we analysed that this model is sensitive to birth rate of predator W and Growth rate of G. Moreover, for every equilibrium state, the predator W count in Agent based Model is 3 times lesser than wolves count in system dynamics model.

We also found that W is very much dependent on availability of Grass although W has no direct predation on Grass.

Following are the results when we compared the agent based model and equivalent system dynamics model when initial values for the parameters were:

Initial number of sheep:148, initial number of wolve:31, sheep-max-intial-energy:4, wolf-gain-from-food:8, sheep-

reproduce-rate:	0.04,	wolves-reproduce-rate:	0.06,
predation-rate:	0.0001,	wolves-death-rate:	0.15,
Grass-eaten-rate:	0.00058 and	Grass-Growth-probability:	0.20.

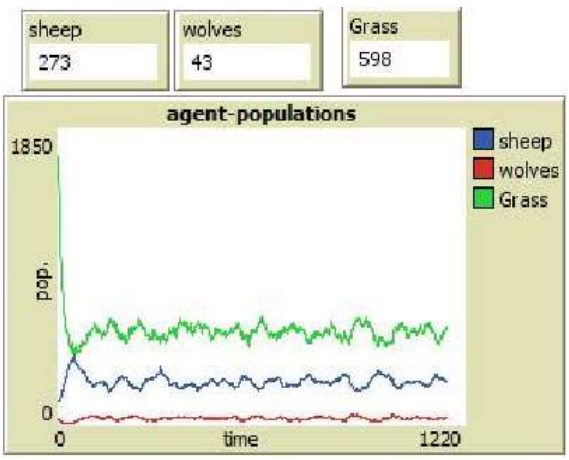

Figure. 2 Graph of systems dynamic model

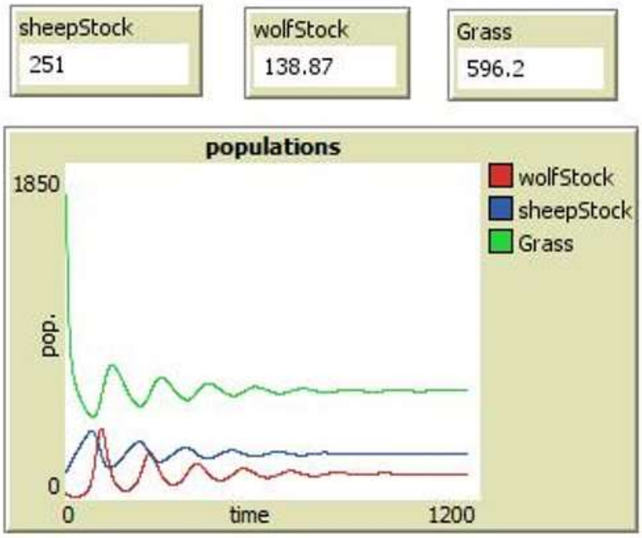

Figure. 3 Graph of extended agent-based model

3. CONCLUSION

We proposed a new agent-based model that extended the previously available Wolves-Sheep predation (Docked model) available in NetLogo. We have implemented a new spatial property (grass) to make previously build Agent Based Model more realistic. We used equivalent aggregated model to visualize and compare behaviors of these two models over time. We After that we observed that addition of this new third Agent property has changed the equilibrium of the both agents based model and equivalent System dynamics model. We concluded that in each equilibrium state the number of wolves is approx. 3 times lesser than in aggregated model. It made easier to analyze the natural eco-systems with a food chain. Further extensions to this model will take us nearer to reality.

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