Agent-based modelling of the effect of poaching on elephants in Eastern Africa using Netlogo

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ABSTRACT

Wildlife poaching is the illegal hunting and killing of wild animals. Poaching occurs worldwide, with thousands of animal species on the target list [1]. In the continent currently, Poaching is a widespread problem, it is moving at an unstable rate which can lead to the loss of some wildlife species in the region. The open ivory market in China is fuelling illegal killings and trafficking of wildlife in Africa [18], this is threatening to cut the existence of some of these species [2]. It is crucial to monitor the impacts this illegal killing has on wildlife, as the ecosystem strives for the balance of wildlife population [3]. As of 1930, the population of wild elephants in the African continent was about 10 million. Unfortunately, in just about a century, poaching and conflicts have seriously decimated their population. Presently, the number of roaming Elephants across Africa is down to about 415,000. It is worth noting that there has been some awareness of the issue in some documentaries but poaching keeps driving Elephant and many other wildlife to near extinction [4]. In this project, I review existing wild-life poaching literature on East African Elephant conservation [5] and uses this information to build an Agent-based model using Netlogo. The main focus of this model is to simulate effective ways to achieve stable conservations of continued existence of this Africa's gentle giants (Elephants). The Netlogo [6] software uses complex parameters to visualize the outcome in real-time so that researchers, experts, and stakeholders in wildlife conservation can monitor poaching variables and act accordingly.

Keywords

Agent-based modeling, Netlogo, Poaching, Elephants, Eastern Africa, conservation, Population, Extinction.

INTRODUCTION

There is a poaching crisis in Africa due to the poaching of elephants for their ivory, mainly demanded from China which is leading to a decline in elephant populations across Africa [7], Just between 2010 to 2012, the number of Elephants illegally killed was over a hundred thousand [8]. Currently, the rate of poaching elephants in Africa seems to be decreasing, but the processes driving poaching rates need to be understood to evaluate conservation interventions [9].

The African region that has been ravaged the most by poachers in recent times is Eastern Africa, experiencing roughly 50% decline in Elephants numbers since the year 2007, and the killings were mostly done in Tanzania, with a reduction of more than 60% in the animal's population [10]. Itt is glad to see that Elephant populations in Uganda, Kenya, Rwanda, and Ethiopia have been stable or increasing since 2007. Elephants' population has also risen in South Sudan as there has been deliberate and vast Elephant population survey carried out since about thirty years ago after the year 2006. Unfortunately, there studies are showing there is reason to believe Elephants are now vanished from Somalia [11].

RELATED WORK

Agent-based modelling has made great strides in recent times, which has prompted researchers to use agents to simulate real-world problems and to propose solutions by studying the behaviour of these agents. The Netlogo agent-based modelling framework was used in a study [12], to examine the hunting theory, inspired by the book, "The Third Chimpanzee" [17] which was proposed by the renowned author J. Diamond, which suggests that Native Americans who migrated to the Americas were majorly responsible for the extinction and total wiping out of big mammals, the likes of the mammoths and American lions, just to mention a few. These animals had evolved without human contact, making them tame and easily hunted by humans. This theory could explain the simultaneous extinction of these species at around the same time as the arrival of humans in the Americas. Another Netlogo model [13], from the Netlogo Libraries, investigates the structure and sustainability of a predator-prey environment. An ecosystem in the model would be considered not stable if it would lead to the extinction of any of the animals, whereas an ecosystem would be considered stable if it can sustain both animal species over time, even if there is a fluctuation in population.

SYSTEM DESIGN AND IMPLEMENTATION

[14] **NetLogo**, an ABM (Agent-based model) programming language useful for modelling environments that are designed for simulating and can be implemented in various kinds of projects through the use of multiple agents [19] . It is especially effective for modelling systems that are constantly evolving and becoming more complex."

NetLogo is a tool that allows students to test simulations and investigate how they behave in different scenarios. It serves as a platform for all kinds of researchers to develop and create project models. NetLogo creates the chance for people in the academic field like students and professors to easily make use of, but also has advanced features for professionals in various fields. The NetLogo framework is an agent-based modeling based on Java virtual machine, meaning it can be openly used to create very complex models, with room to evolve in the system. The concept used is multi-agent modeling, where agents act in an independent manner, just in the direction of instructions to produce a simulation. The Netlogo language and syntax are straightforward and easy to learn, making it a popular choice for researchers to conduct automatic experiments. The application of

NetLogo in this project is to model the poaching of elephants in East Africa and develop strategies to maintain a stable population and prevent extinction.

Graphics User Interface (GUI)

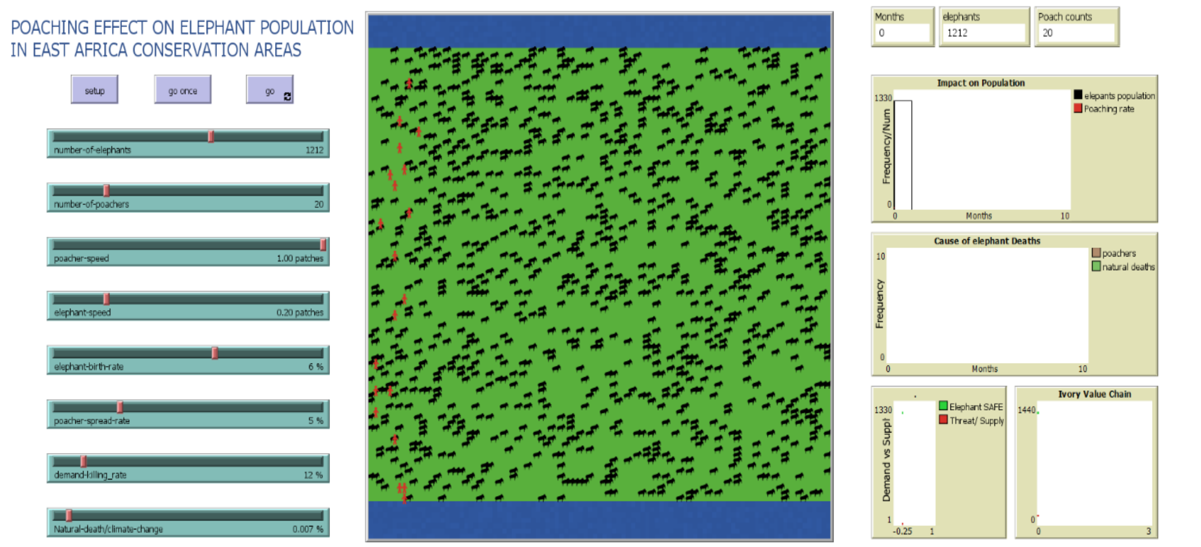


Fig 1: Netlogo UI for the simulation of Elephant poaching

The (GUI) Graphical user interface serves as a control for the variables in the application. The illustration above shows the parameters required to run the simulation of the multi-agents in respect to this project model, to investigate inputs for a stable existence of elephants in the Tanzanian wildlife conservation area. The death of elephants can be caused either by poaching or climate change. The model uses multiple agents, including elephants and poachers (humans), to simulate this process. Poachers enter the conservation area and hunt elephants for their ivory, which leads to a decrease in the elephant population. This causes the value of ivory to increase, which increases poaching and ultimately results in the extinction of elephants in this East African wildlife conservation. In addition, the model considers that in each patch of land where elephants live, then there is a probability of climate change affecting it, which can lead to the natural death of elephants on those patches.

Colour Codes:

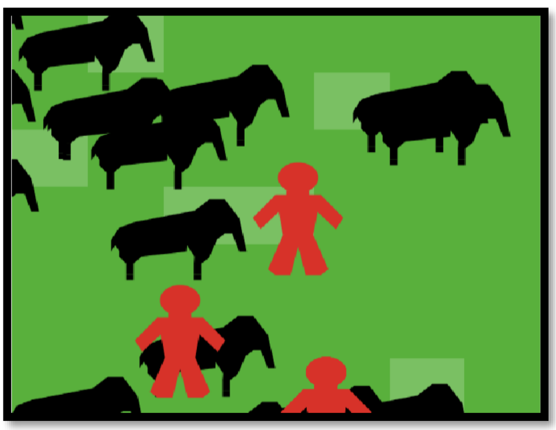


Fig 2: Netlogo user interface Close inspection of Agents and patches

I. Elephants: Black Elephants represent the elephants in the conservation park.

II. Poachers: Red humans represent the poachers approaching from the left.

III. Conservation land: green patches represent the conservation park land.

IV. Climate change: Light green patches represent climate change.

V. River: Blue patches represents the water body defining the parking area.

Input Fields

I. Number-of-elephants: This slider controls Elephant population starting in the simulation. The user is free to change the value of population according to preference. The minimum value for Elephants initial count is 100, using a 1 poacher to 20 elephants' ratio for the sake of this project.

figure 3: Number-of-elephants input slider

II. Number of poachers: This slider sets the number of Poachers in the simulation. Users can increase and decrease the numbers as necessary. 0 is the minimum number of poachers because the goal is to eradicate poaching in the conservation park. The system gets the Poachers (Red) population and sets it in the frame.

figure 4: Number-of-poachers input slider

III. Poacher-speed: This sets how fast the poachers move and strike against the elephants, this depends on how easy it is for them to move along the area. The more relaxed the security, the faster they operate.

figure 5: Poacher-speed input slider

IV. Elephant-speed: This in turn controls how fast the elephants move, since they are intelligent animals to a degree, their behaviour has been affected and this is the rate at which they evade poaching, which is usually low, as they normally don't stand a chance against the poachers.

figure 6: Elephant-speed input slider

V. Elephant-birth-rate: This is the percentage at which the Elephants reproduce in this simulation.

figure 7: Elephant-birth-rate input slider

VI. poacher-spread-rate: The rate of scope the poacher covers in the conservation area. The chance of further incursion is calculated by the system using the value inputted, and if the rate goes up, this encourages more poaching.

figure 8: poacher-spread-rate input slider

VII. demand-killing-rate: The rate of demand for ivory is equal to the rate of illegal killings of the Elephants.

figure 9: demand-killing-rate input slider

VIII. Natural-death/climate-change: The probability of an Elephant dying naturally or of climate change causes. The system uses the probability in every natural incident in the conservation area, the higher the value set, the more patches (light green) the more natural and climate change caused deaths.

figure 10: Natural-death/climate-change input slider

Output Fields:

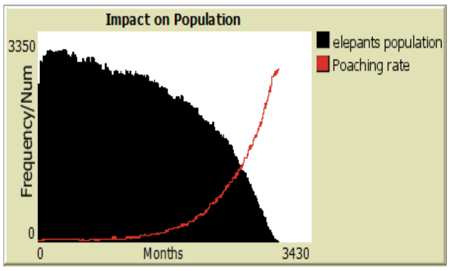
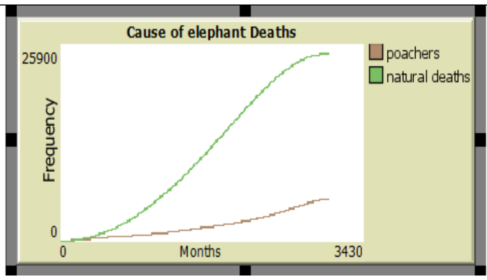
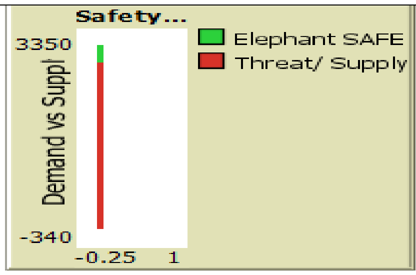
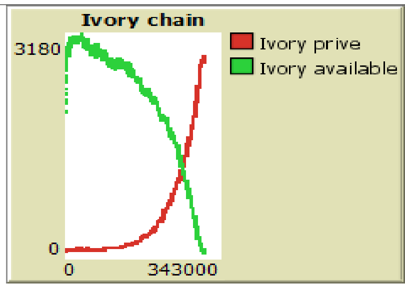
Outputs	Description	Visualization
Months	The number of months before the simulation outcome.	
elephants	The population of elephants remaining in the conservation area	
Poach counts	*Total number of active poachers in the conservation area*	
Impact on Population	Plot showing elephants population run along the months in the conservation area	
Cause of elephant's deaths	A Plot showing the major cause of death of elephants in the conservation area, either Poaching or Natural/climate change phenomenon	
Safety bar	This stick bar plots showing the relationship between demand/supply with the safety level of the elephants in the conservation area.	
Ivory value chain	This plot show the price value of ivory rises with the scarcity of ivory, leading to it being sought after, and thereby poaching	

Table 1: Output Fields

RESULTS AND DISCUSSION

The effectiveness of the models for preventing elephant extinction can be tested by selecting a set of inputs that simulate different ways to address the poaching crisis in Africa. As previously mentioned, the poaching crisis in Eastern Africa is a major threat to elephant populations, with over 100,000 elephants illegally killed between 2010 and 2012 due to the demand and open ivory market in China [6]. Despite the fact that Elephant poaching has reduced in some parts of Africa in very recent years, more needs to be done to drive the poaching completely out and implement effective conservation interventions [9]. It is important to address this crisis and protect these endangered species [11]. If the poaching activities are not addressed, the researchers in [3] suggest that there is a risk of elephant extinction. The following are simulation tests with varying parameters and visual outcomes.

SIMULATION TEST 1:

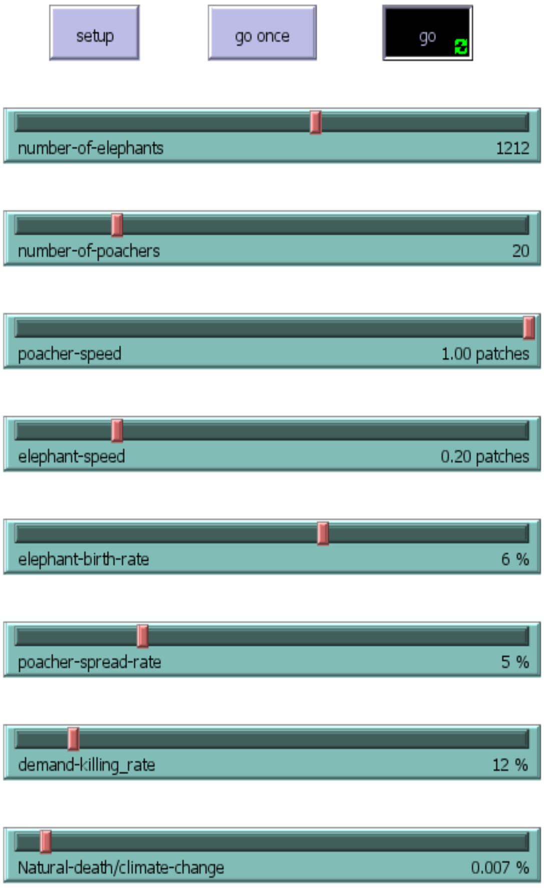
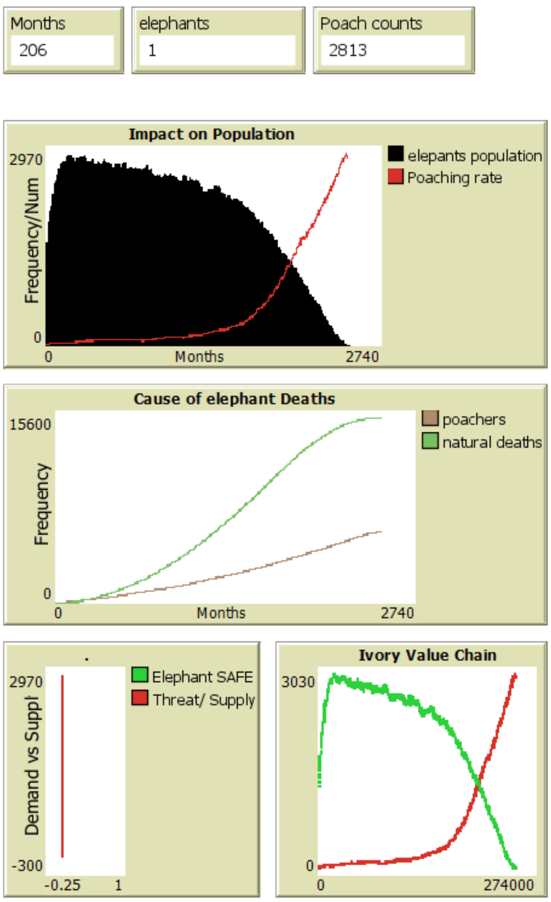
INPUT PARAMETERS	OUTPUT VISUALS
	

Table 2: Test Values

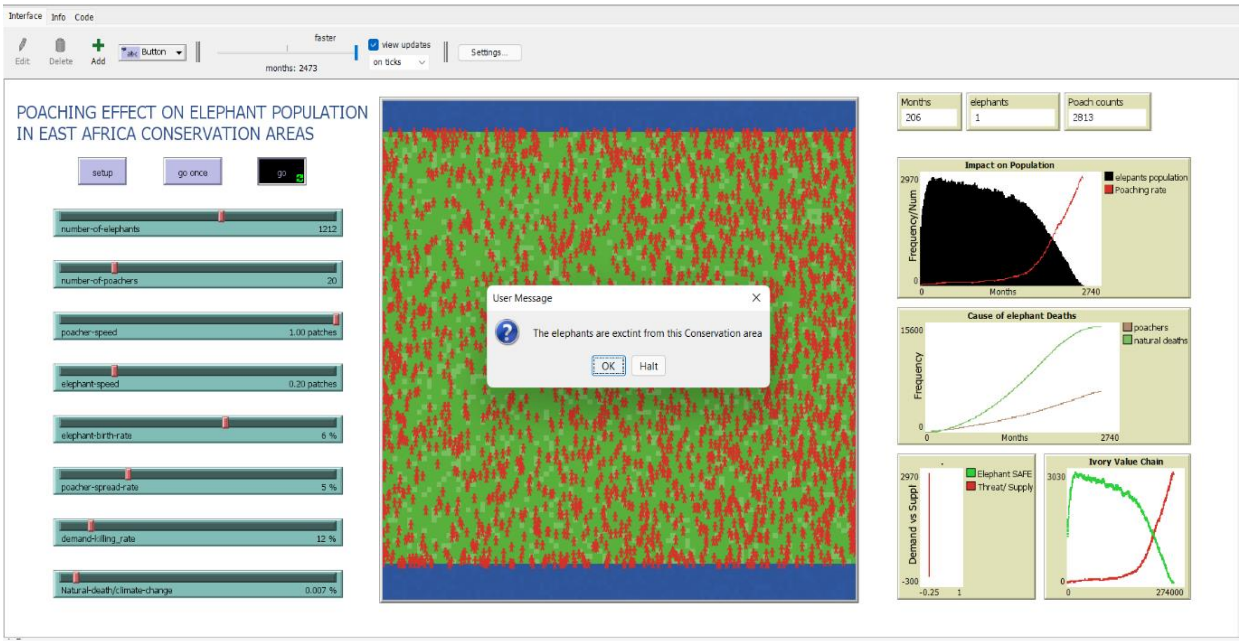


figure 11: Simulation resulted to the Elephants Extinction in the conservation

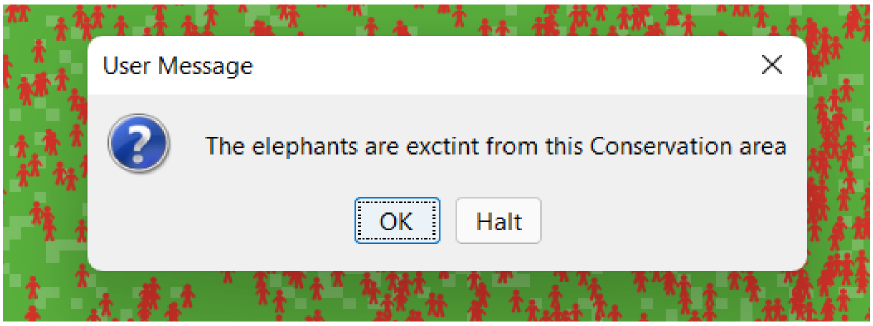


figure 12: Simulation resulted to the Elephants Extinction in the conservation

The first simulation values, parameters and outcome are shown in Table 2 and Fig. 12. The Elephants became extinct in the conservation park after 206 months. That came because of a huge increase in poaching count 2813. Elephants were depleted by a 12% poaching rate at a 5% spread rate. Natural death and climate change were only responsible for about a third of the overall death, Poaching causes a scarcity in the ivory market, creating high demand for ivory, which causes more poaching. So, we can see that this parameter results in an unstable ecosystem.

SIMULATION TEST 2:

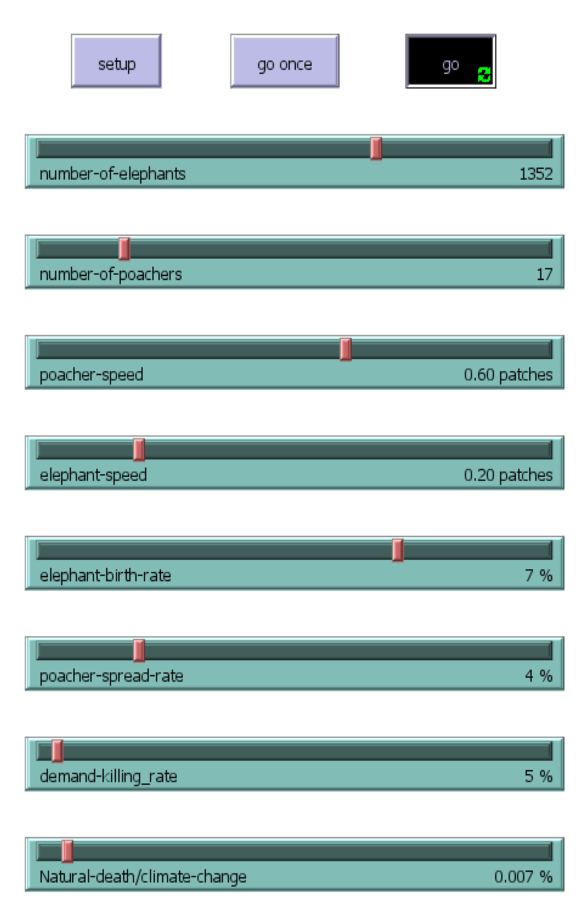
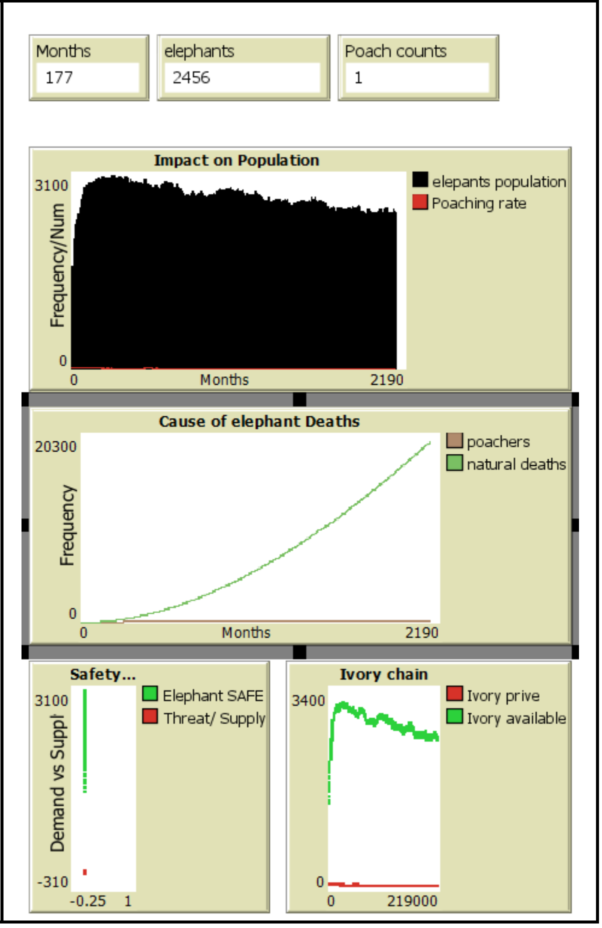
INPUT PARAMETERS	OUTPUT VISUALS
	

Table 3: Test Values

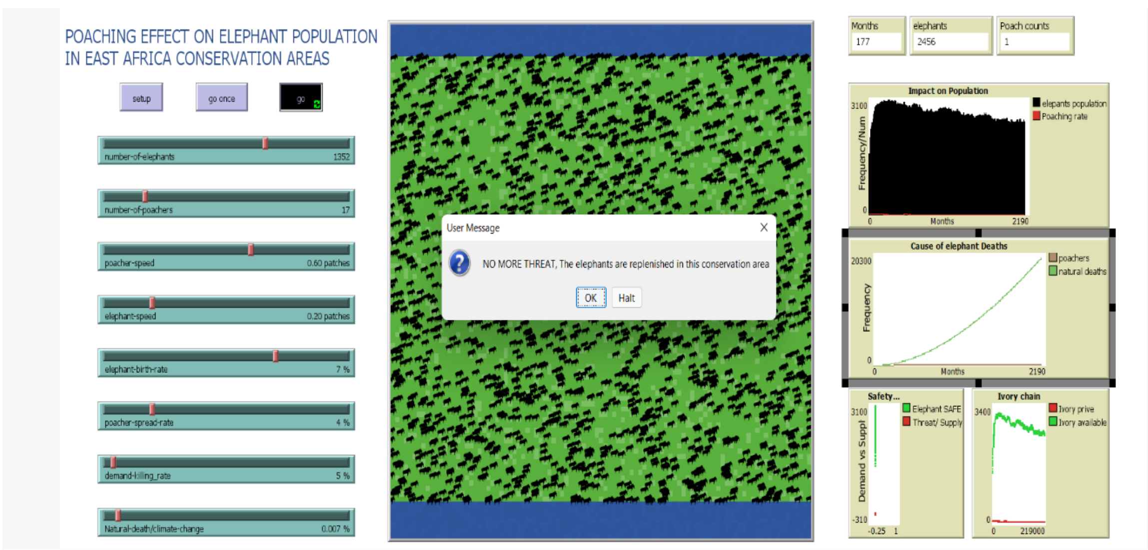


figure 13: Simulation resulting to elephant's Replenishing in the conservation

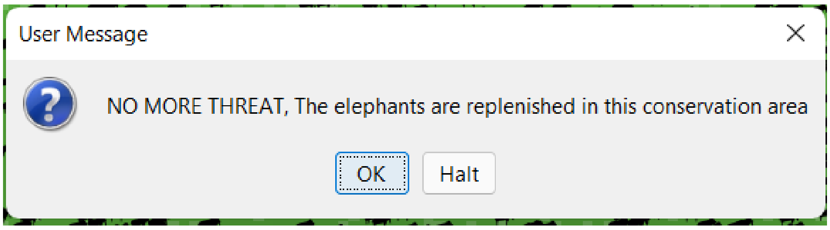


figure 14: Simulation resulting to the Elephants Replenishing in the conservation

Now this second simulation results in a stable ecosystem, where the Elephants get replenished, reproducing at a sustainable rate across the east African conservation park. This result came in 177 months, with the killing poachers spread rate at 5% and 4%, respectively. In this test, the major cause of death for the elephants are climate change and nature.

According to the models, it appears that adopting strategies from the second simulation may be the most optimal for achieving sustainability in the long term. These strategies have the highest probability of achieving an effective stable ecosystem.

CONCLUSION AND FUTURE WORK

Artificial intelligence is fast becoming a dependable source for finding past, present and future solutions. Agent-based modeling is a useful tool for tackling complex problems that are currently beyond human understanding. This method involves creating virtual models of systems such as the solar system, biological environment, medicine and more, which can help us predict and visualize potential outcomes. In this specific project, Netlogo Agent-based model was used to study the impacts of poaching on East African Elephants. Particularly looking at this region, given it is the most affected by poaching in recent times. Many Regions like west and central Africa has lost their elephant population to conflicts and poaching, but now the world needs to look at these models and projections made by researchers to take the necessary steps to avoid the loss of these beautiful mammals. Although the simulation was conducted using intricate parameters, there are still ecological and geographical factors that can be taken into account for future improvement.

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I am eternally grateful to Hiba Alsmadi and. Dr. Alessandro Di Stefano for giving this chance to explore and discover the various Artificial intelligence application techniques. The sessions of the Netlogo Agent-based modeling and python MESA were instrumental in strengthening my knowledge on ABM. I also want to thank Seth Tisue and Uri Wilensky for creating Netlogo, this agent-based modeling framework, without it this project would not have been.

PERSONAL DEVELOPMENT AND LEARNING OUTCOME

Gaining an understanding of the concept of poaching, the reasons why elephants are particularly susceptible to poaching, and the impacts of elephant poaching can help individuals learn more about how to protect elephants from poaching. The project yielded valuable learning outcome. In the start of this project, I possessed absolutely zero experience in the development and practice of Agent based modelling. However, through my participation in various Netlogo and python MESA tutorials, I became more increasingly drawn to Agent-based modelling. I carried out some personal lab experiments basically running and understanding Netlogo and Python Mesa and I came to the conclusion that Netlogo application was more user-friendly for beginners like me. I then chose Netlogo as my work tool.

My interest in this topic was sparked after watching the documentary The Ivory Game on Netflix [15]. I remembered that in my home country, located in West Africa, elephants have been depleted and are said to be extinct in most areas that used to host these majestic animals. To understand the basics of Netlogo, I utilized a tutorial by the Complexity Explorer youtube channel [16], with Prof. Bill Rand as the tutor. The youtube tutorial greatly aided my understanding of Netlogo. Afterward, I explored Netlogo library and attempted tried to comprehend the coding. As expected, coming from a non-computer science background, the coding logic was quite challenging for me, However, with consistent study and dedication to the tutorials, I eventually learned how it all works. My Netlogo simulation has eight input values, seven output values, and two options for user message pop-ups depending on the outcome. After the project is graded, I plan to publish my model to aid students coming after me to learn about the Netlogo application and simulation. Comments were richly added into the code to make it easier for comprehension. Through the course of this my report, I carried out thorough literature review and properly referenced my sources.

In conclusion, I would say I have gained comprehensive knowledge generally on the ABM (Agent-based modeling) as a topic, and the basic understanding of how to relate it to any kind of real life scenario building it on a model and then analyzing the result into a written detailed report, explaining all process taken. For the second semester in my program, I would really make more effort to improve my Netlogo skills and then move to exploring how python MESA works. Since in have had quality experience with Netlogo, I believe that will make learning MESA a bit easier.

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