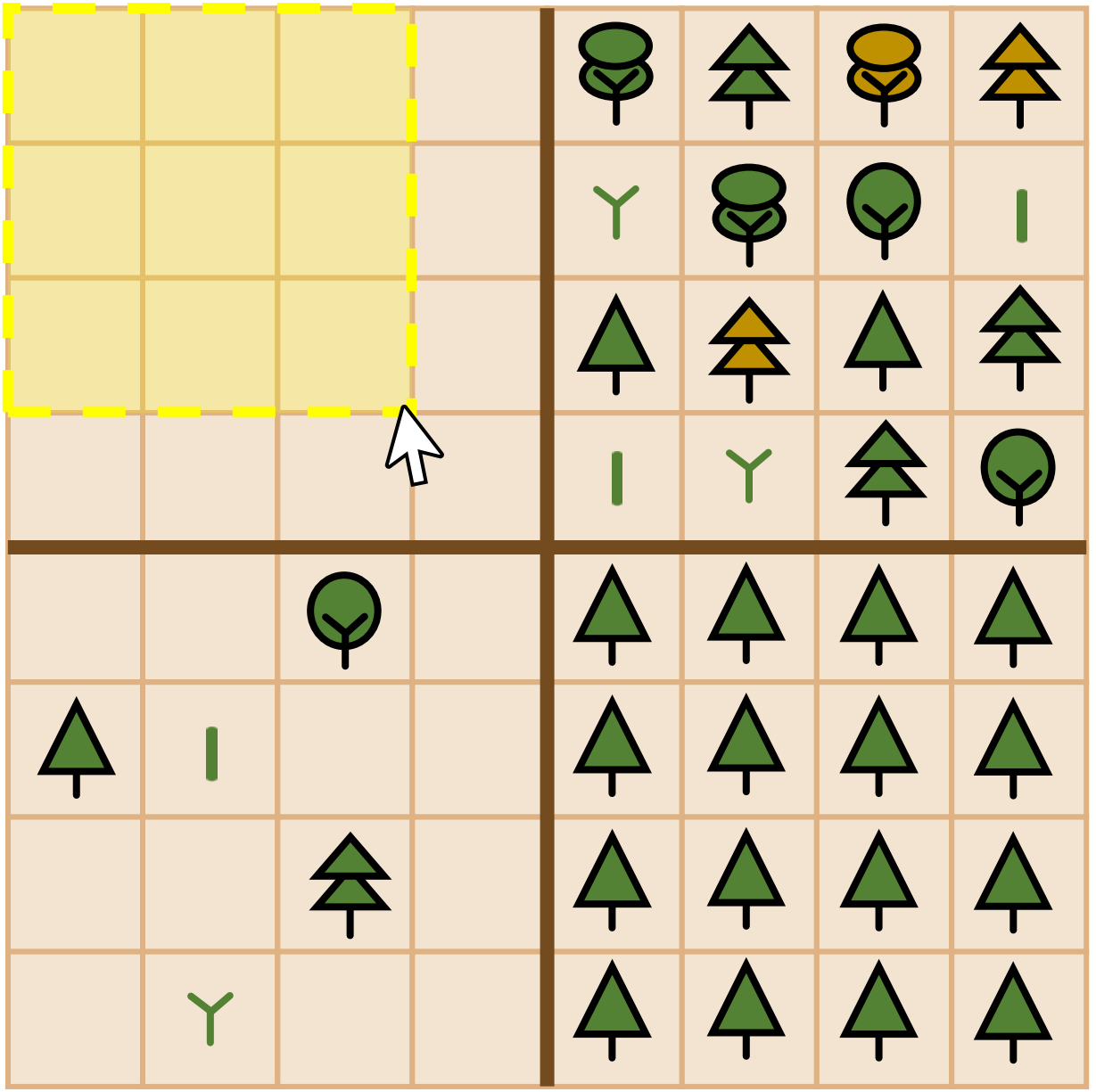
Exploring the use of microworlds to teach about forest management and climate change.



Student Name: *Gayathri Girish Nair*
Student ID: *23340334*
Stream: *Data Science*
Supervisor Name: *Brendan Tangney*

Student Name: Gayathri Girish Nair	Student ID: 23340334	Stream: Data Science	Supervisor Name: Brendan Tangney

1. Research Question/Aim: Can a microworld, simulating forest management scenarios using Agent-Based Modelling (ABM), engage users? Can such a teaching tool change the attitude of learners regarding use of forests as a nature-based solution against rapid climate change?

2. Research Objectives

2.1. Understand how forests sequester carbon and are managed.
2.2. Identify main mechanisms/behaviours (e.g., tree aging, carbon capturing, etc) and properties (e.g., biodiversity, growth rate, carbon levels, etc) to model into the microworld as well as learning outcomes of the application (app).
2.3. Establish rules that govern user interactions and app responses to user actions/changes in properties (e.g., greater biodiversity implies more carbon capture, planting trees cheaper than logging them, etc).
2.4. Explore different ways of mathematically expressing identified rules and mechanisms.
2.5. Verify soundness of design choices (world rules, mathematical expressions, possible user actions, etc).
2.6. Determine a practical user interface (UI) design that is likely to be engaging and grants a good learning experience.
2.7. Identify tools that facilitate app development (UI, computations).

3. Approach/Method to achieve objectives

3.1. Research Methods: **1. Literature Review:** To meet objectives 2.1 to 2.4 and 2.7. **2. Stakeholder Consultation:** This project involves 2 stakeholders, the project supervisor (Computer Science Professor at TCD) who is highly knowledgeable in technology enabled teaching and a domain expert, Dr. Silvia Caldararu (Assistant Botany Professor at TCD) who brings a wealth of knowledge regarding impact of climate change on plants and effects on the carbon cycle. Realizing objectives 2.1, 2.2, 2.5 and 2.6 shall involve conversing with these experts and incorporation of their guidance to ensure correctness of approach. **3. Building Prototypes:** For evaluation through experiments so that objective 2.5 can be met. **4. Questionnaire:** For field experiment evaluation. **5. Experiments:** A feasibility experiment shall be conducted with a Minimum Viable Product (MVP) as proof of concept to confirm soundness of development choices. A low-fidelity prototype and the MVP shall be subject to a trial experiment to determine whether the simulated system behaves as expected. Finally, a field experiment shall be conducted with a refined version of the app wherein it shall be tested by transition year (approx. age 16) or undergraduate students. Feedback shall be collected via a questionnaire.
3.2. Dissertation Method: **1.** Literature review. **2.** Identify mechanisms to model. **3.** Capture envisioned model through rules and diagrams. **4.** Create a mock-up of the UI. **5.** Make low-fidelity prototype (pen & paper). 6. Test low-fi prototype (trial experiment 1). **7.** Make improvements. **8.** Develop a Minimum Viable Product (MVP) or high-fidelity prototype. **9.** Test hi-fi prototype (trial experiment 2). **10.** Refine application. **11.** Conduct field experiment. **12.** Refine and complete the dissertation that was being written throughout the process.

4. Evaluation

4.1. Let students use the microworld in a bridge to college workshop for a set amount of time.
4.2. Gather and compare learners' thoughts on using forests to combat climate change before and after using the app to gauge changes in attitude towards the topic.
4.3. Collect user ratings to determine distribution of different levels of engagement.
4.4. Compare forest management strategies adopted by users to meet set objectives in the microworld against real-world best practices to understand effectiveness of microworlds and explorative learning w.r.t meeting intended learning objectives.

5. Contribution of your research project.

5.1. A web application incorporating an Agent-Based Model (ABM) to simulate land that can be forested and effects of forest management strategies on atmospheric carbon levels, which can be used to educate non-expert audiences about challenges/best practices w.r.t climate aware economically sustainable forest management.
5.2. Analysis of usability and level of engagement scores.
5.3. Comparison report of attitude of learners towards using forests to combat climate change before v/s after using the learning tool.

Motivation Statement

Forests absorb 30% of global emissions per year [1]. They are integral to combating climate change but are fragile. If enough of a forest is cleared, they turn from absorbing more carbon than they emit, to doing the opposite which would be catastrophic. This is already beginning to happen and will worsen if ignored. [2, 3] Widespread education/awareness is thus important to ensure a sustainable future.

Effective education demands increased user engagement. Education technology approaches involving microworlds has proved successful at achieving this in other areas [4] but remain underutilised in the field of forest management with few examples of similar projects [5] existing today and none, to the best of knowledge so far, aimed at educating non-expert audiences about forestry and climate change.

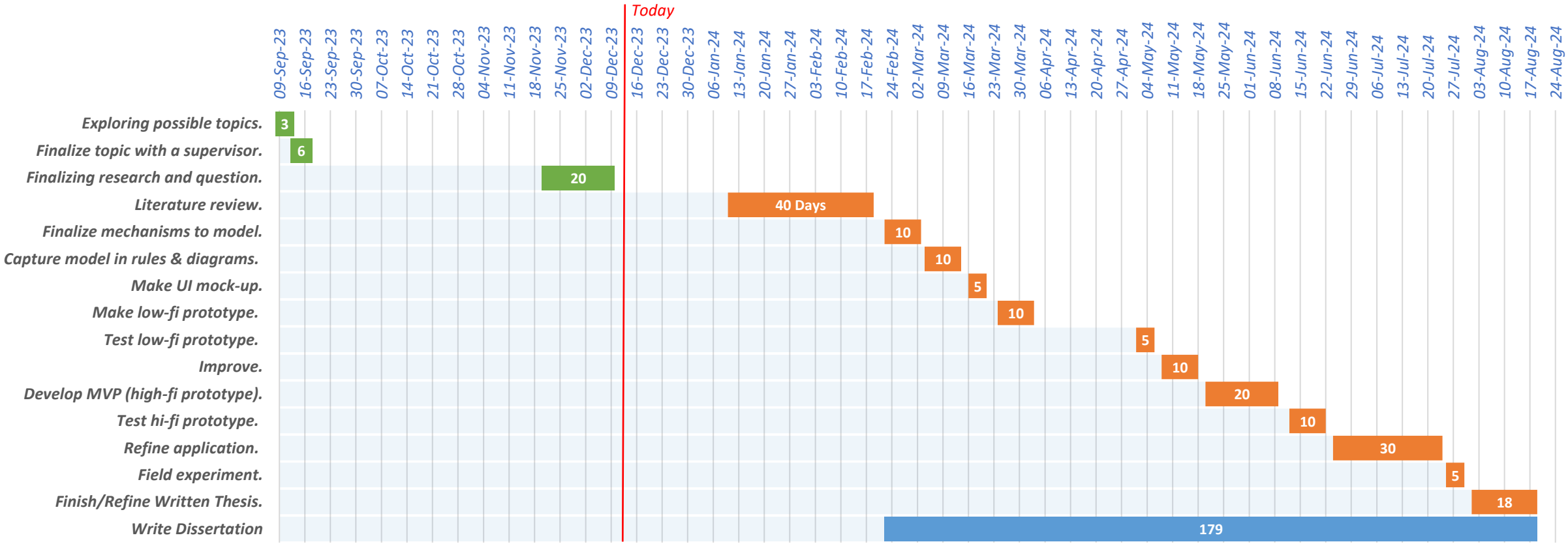
Hence, this research focuses on the design, implementation, and evaluation of a microworld to teach adolescents about forest management and climate change.

The aim here is not to build a scientifically accurate, detailed simulation. For teaching purposes, it's more important to build a conceptual model that captures real-world mechanisms in sufficient detail and accuracy while still being simple enough so as not to overwhelm/distract from learning objectives. Thus, this research shall adopt an Agent Based Modelling (ABM) approach to simulate the microworld. [5-7]

Reference List

1. Program, U.N.D. Forests can help us limit climate change – here is how. 2023.
2. Daigneault, A., et al., How the future of the global forest sink depends on timber demand, forest management, and carbon policies. Global Environmental Change-Human and Policy Dimensions, 2022. 76.
3. Fergesen, J. Trees Help Protect the Planet From Climate Change. But The World Isn't Doing Enough to Protect Forests. 2022.
4. Hoyles, C., R. Noss, and R. Adamson, Rethinking the Microworld Idea. Journal of Educational Computing Research, 2002. 27(1): p. 29-53.
5. Fouqueray, T., et al., Interdisciplinary modeling and participatory simulation of forest management to foster adaptation to climate change. Environmental Modelling & Software, 2022. 151: p. 105338.
6. Chen, J., et al., The Pocketworld Playground: Engaging Online, Out-of-School Learners with Agent-based Programming, in Proceedings of the 22nd Annual ACM Interaction Design and Children Conference. 2023, Association for Computing Machinery: Chicago, IL, USA. p. 267–277.
7. Rivera-Monroy, V.H., et al., Are Existing Modeling Tools Useful to Evaluate Outcomes in Mangrove Restoration and Rehabilitation Projects? A Minireview. Forests, 2022. 13(10): p. 1638.
8. Hensbergen, H.v., K. Shono, and J. Cedergren, A guide to multiple-use forest management planning for small and medium forest enterprises. Vol. 39. 2023, Rome: Food and Agriculture Organization of the United Nations. 144.
9. Da Silva, A.F., et al. NetZeroCO2, an AI framework for accelerated nature-based carbon sequestration. 2022. IEEE.
10. Applegate, P.K.J. Tall and old or dense and young: Which kind of forest is better for the climate? 2019.
11. Montaigne, F. Why Keeping Mature Forests Intact Is Key to the Climate Fight. 2019.
12. Peng, L., et al., The carbon costs of global wood harvests. Nature, 2023. 620(7972): p. 110-115.
13. Lindner, M., et al., Climate change and European forests: What do we know, what are the uncertainties, and what are the implications for forest management? Journal of Environmental Management, 2014. 146: p. 69-83.
14. West, T.A.P., et al., Action needed to make carbon offsets from forest conservation work for climate change mitigation. Science, 2023. 381(6660): p. 873-877.

Gantt Chart



Regarding writing of the dissertation, the plan is to write parts of it in parallel as soon as the literature review step is complete so that by 01 August 2024, the dissertation document is almost complete and need only be refined and updated to reflect feedback from supervisor in the last few days until submission.

The first gap around 25 December 2023 is on account of the winter break and the second one around April 2024 is considering end of Hillary term exams.

Literature Review Protocol

Topic	Description of topic
Purpose of the review	To gain background knowledge (regarding existing similar work, forest carbon sequestration, forest management, ABM, microworlds), identify gaps/limitations of existing work that this application can address, determine core mechanisms/entities that needs to be incorporated into the microworld, explore ways of capturing these mechanisms mathematically, and to get a sense of tools/data that may be used for development.
Rationale for the review	Simulating natural processes is non-trivial given large variability and countless interdependencies between systems. Thus, it's important to identify the most relevant mechanisms that are to be incorporated into the simulation to keep it sufficiently realistic while at the same time, simple enough to be easily comprehended. This demands thorough research of the domain (forests, carbon sequestration, management) and analysis of methods adopted by existing similar projects. Furthermore, my unfamiliarity with ABM and microworld implementation demands research around these topics to ensure their correct application within the project.
Information sources	IEEE Digital Library, ACM Digital Library, Science Direct, Web of Science, Google Scholar, Mongabay (https://news.mongabay.com/), Teagasc (https://www.teagasc.ie/), Forestry Focus (www.forestryfocus.ie), Food and Agricultural Organization of the United Nations (www.fao.org).
Search string	microworld, forest* AND (agent based model* OR ABM), forest* AND (microworld OR management OR simulation OR game OR emulation), forest* AND (teaching OR learning OR e-learning) AND (tool OR app*), reforestation, proforestation, forest* AND (econom* OR financ* OR budget OR expen*), forest* AND ("climate change" OR "global warming"), forest* AND "simulation" AND (carbon OR CO2) AND (sequestration OR capture OR sinks), agent based model AND (teaching OR learning OR e-learning).
Eligibility criteria	Years [2010 – 2023/24] preferred. Older years may be considered only when material is scarce or if the older publication is especially informative/important. Only works in English shall be considered. Journal articles are first preference, followed by conference proceedings, books, educational institution publications, government publications, news articles and other grey literature in decreasing order of preference. Review articles shall be preferred when exploring a topic for the first time. On subsequent searches, more technical papers with narrower focus shall be considered. Articles covering at least 2 topics of interest together (ABM & Forest Management, Forest Management & Carbon Capture, ABM & Teaching Tool, etc.) are deemed eligible for exploration.
Data Items to be extracted from literature	Title, author(s), year, abstract/important parts of it, keywords, key insights (findings, discussions, conclusions), methods, interesting ideas, scope for improvement, important abbreviations, useful citations, URL.

Ethics Statement

Yes.

This project requires ethics approval for trial and field experiments.

All experiments are of a similar nature wherein the participant tries to use a prototype or latest version of the application and shares their feedback regarding usefulness and user experience. No sensitive data shall be collected. Participants shall be informed in full detail about the reason for the experiment, exactly what they can expect to be doing as part of it and what data shall be collected.

A pre-existing ethics approval is available under the Bridge to College program for transition year student participants.

Skills List

	Skills Possessed	Skills Hoping to Develop
Research	• Structured reading (am familiar with the efficient way to read journal articles – abstract, figures/tables, discussion/conclusion, introduction, rest of the document). • Project planning. • Self-management. • Analysing read material. • Basic academic writing.	• Reading speed and efficiency. • Better time management. • Improve critical thinking. • Literature search skills. • Research documentation (keep track of material read, and thoughts on it better like through a research journal). • Use reference management tools like EndNote. • Get more comfortable with ambiguity.
Technical	• Have some experience with basic web development tools like HTML, CSS, JS, ReactJS, D3.js, three.js and NextJS (shall be used to build application UI). • Familiar with some database technologies like MySQL, Google Firestore and PostgreSQL (may be used for managing app data). • Good grasp of Python and fair knowledge of Java (can be useful for data analysis, complex calculations or in conjuncture with backend frameworks like Django). • Good understanding of UML diagramming and Object-Oriented Programming. • LaTeX.	• Agent Based Modelling concepts and associated tools to facilitate this like the JavaScript library Agentscript. • Better command of web development (especially backend technology since I'm currently more familiar with front end development) and data management tools. • Possibly learn to use some new tools along the way as may be identified as suitable for this project after detailed literature review.