Abstract
Current methods for visualizing forest rely on geospatial and remote sensed data. Such data can be used to create visualization and to perform simulations. Currently, however, these visualizations are often limited to 2D or abstract representations. These methods can be effective for large scale data visualization and low accuracy needs. However, when high detail representations are needed, they fall short. This research has developed a realistic 3D forest visualization prototype that takes detail to the next level, with absolute reproducibility in mind. The high-fidelity visualization includes real-world topography, with real-world tree information. To further enhance the visualization, animals, streams, sound, additional flora, and weather conditions have been added.

Background
There are many needs for an accurate and realistic forest visualization. The enhancement of forest ecosystem visualizations allows for a better understanding of needs to protect and conserve forests. Moreover, high-fidelity visualizations can help guide decisions regarding projects surrounding the adaptation and mitigation of climate change. Furthermore, realistic forest visualizations can be used for personnel training in the forestry domain. As it allows for a safe and cost-effective method for immersing novice forestry professionals.

Methodology
- To bridge the gap between geospatial data and high-fidelity visualizations, game engines have been chosen as the tool of choice. In this case, Unreal Engine 5 (UE) was used, as it allows for a high degree of flexibility.
- To visualize the terrain, we were provided with a Digital Terrain Model (DEM) of the entirety of Elliott State Forest located in Central Oregon. We utilize UE’s georeferencing capability to place the DEM at its true Cartesian coordinates.
- Various ground surfaces such as dirt, grass, and water were visualized by employing Us landscape material functionality. ArcGIS Pro was used to determine the distribution and blending of these surfaces based on geospatial data. The corresponding methodology is shown in Figure 1. Additionally, 3D objects such as vegetation and fallen branches are placed in the environment.
- Trees are an essential part of forests. We used a tree inventory dataset to gather information about individual trees. In UE, we implemented the functionality to place the trees at the actual location and visualize them based on their attributes. An overview of this process can be seen in Figure 2.
- Variability is extremely important when visualizing a diverse ecosystem. The visualized environment is enhanced by realistic animals and sounds to increase the believability of the representation. Additionally, the user has the option to simulate the forest at any time of day and under conditions such as rain, snow, and clear skies.

Results
Immersive visualizations are dictated by user experience. The main aspect being the frames per second (FPS). With a landscape coming in around 1 square kilometer, we observed 75 FPS on a high-end computer. We learned that in order to increase the FPS, procedural methods need to be used, as well as utilizing instancing with level of detail (LOD) techniques can be used to enhance the FPS even more. Moreover, using surveyed data is needed in order to make a high-fidelity visualization.

Discussions
We showcased the visualization prototype to forestry experts with extensive experience in the field to collect feedback. We summarize our findings as follows:
- Overall, the feedback was positive. All participants agree that 3D visualizations are helpful for supporting decision-making, education, and communicating the effects of forest disturbances.
- In terms of the visual quality of the rendering and the realism, 87% were either extremely or very satisfied, while 6% were either extremely or very satisfied with the accuracy.
- The main shortcoming of was the limited realism of the understory when restoration scenarios were simulated. To address this, we have updated the prototype replace thinned trees with stumps and add debris on the ground.
- As future work, we intend to extend the prototype to include more restoration scenarios and increase the fidelity of visualizing biodiversity.

Acknowledgements
Advisor: Raffaele De Amicis, Arash Shahbaz Badr

This work was conducted at Oregon State University using Federal funds under award #07-379 from the Economic Development Administration, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of the Economic Development Administration or the U.S. Department of Commerce.