Bringing more exploration and interaction to scenario modeling and data visualisation through 3D GIS and Virtual Reality

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Summary

A prototype 3D GIS and Virtual Reality model has been developed to present future scenarios of woodland expansion and climate data visualisation. Spatial Multi-criteria Analysis has been applied to decide where to plant new forests, recognizing a range of land-use objectives. 3D responsive pie and bar charts have been created and integrated with the virtual landscape model which is used to convey attractive and understandable information. Findings show it has potential implications for the planning of future woodland and interactive data visualisation to increase the effectiveness of their use and contribution to wider sustainable ecosystems.

KEYWORDS: Scenario modeling, Data visualisation, Spatial Multi-criteria Analysis, 3D GIS, Virtual Reality

1. Introduction

In our digital world, many data sources are evolving in real time; data often become out of date quickly and can lose their value fast. The modern data-landscape therefore requires quick decisions to be made if the implementation is to be meaningful. Visualization tools have been used increasingly as part of information, consultation, and collaboration in relation to issues of global significance (Rua et al 2011) (Warren-Kretzschmar et al 2014). However, visualization techniques and methods need to be improved to better deal with the complexity of data analysis and enable rapid interpretation.

Scenario modeling provides one tool for considering the implications of a plan or management decision across a range of future possibilities (Steinitz et al., 2003), and therefore also a valuable analytical device for spatial planning (Couclelis, 2005), enabling practitioners to engage with the process of developing coherent storylines that are applicable at a range of scales.

In this paper, the 3D prototype model for future woodland simulation and interactive data visualisation has been developed. The present study aims to raise public awareness of changes in rural areas, focusing on land, forest, and soil, testing responses to scenarios of change.

2. Methodology

This approach combines Spatial Multi-criteria Analysis (sMCA) with interactive GIS-VR platform and immersive forest and climate data visualisation, to showcase scenario models of different tree species and planting densities in Glensaugh which provides an innovative framework to integrate spatial data modelling, analytical capabilities and visualisation.

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2.1 Case Study Background

Glensaugh is located in North-East Scotland in the Grampian foothills. It is managed as an upland livestock farm, just over 1000ha in area, with sheep, cattle, and red deer, improved and extensive pastures, moorland, woodland and peatland. Glensaugh research farm (**Figure 1**) is an important resource to explore the challenges associated with climate change adaptation and mitigation. The woodland expansion at Glensaugh has the potential to support the rural economy, the environment and rural communities. Glensaugh has a long history of environmental data collection. Two automatic recording stations, the automatic weather station and the Birnie Burn hydrological data monitoring are both part of a long-term environmental monitoring study linked to the UK Environmental Change Network (ECN) and stream data direct to the ECN study and their dedicated web pages.

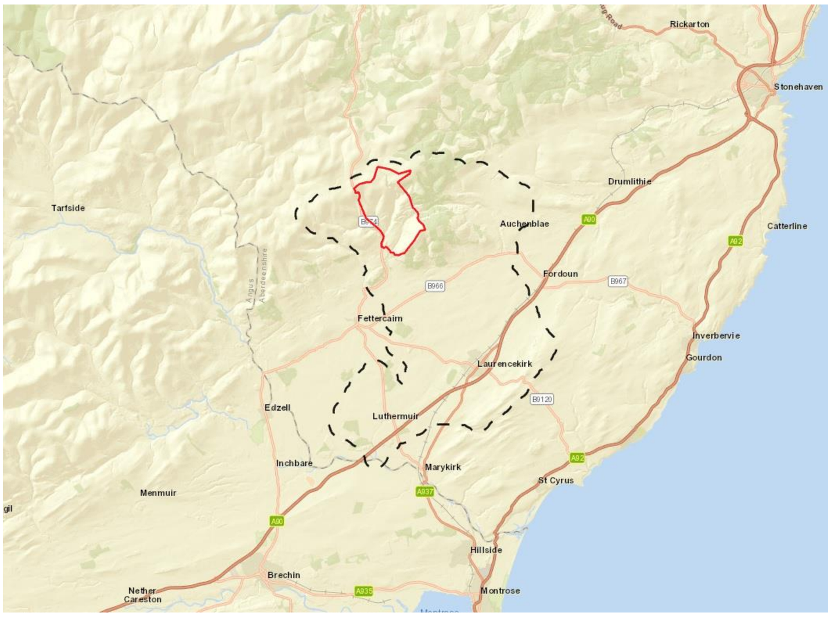

Figure 1 Study area: Glensaugh Farm

2.2 3D Landscape Modeling

3D Visualization has been increased used in scenario analysis and public preferences for landscapes over the last ten years (Stauskis, 2014) (Schnall et al 2012) (Wang et al 2016).
The creation of landscape models represents the first step in the scenario simulation. For this purpose, a 3D model of Glensaugh including agroforestry site (**Figure 2**) was created by using the following dataset:

- Ordnance Survey (5m resolution) Digital Terrain Model extracted for the study area;
- High-resolution aerial imagery used for background landscape textures;
- Spatial data for buildings is from Ordnance Survey MasterMap;
- Spatial data for trees and forests is from Forestry Commission Scotland

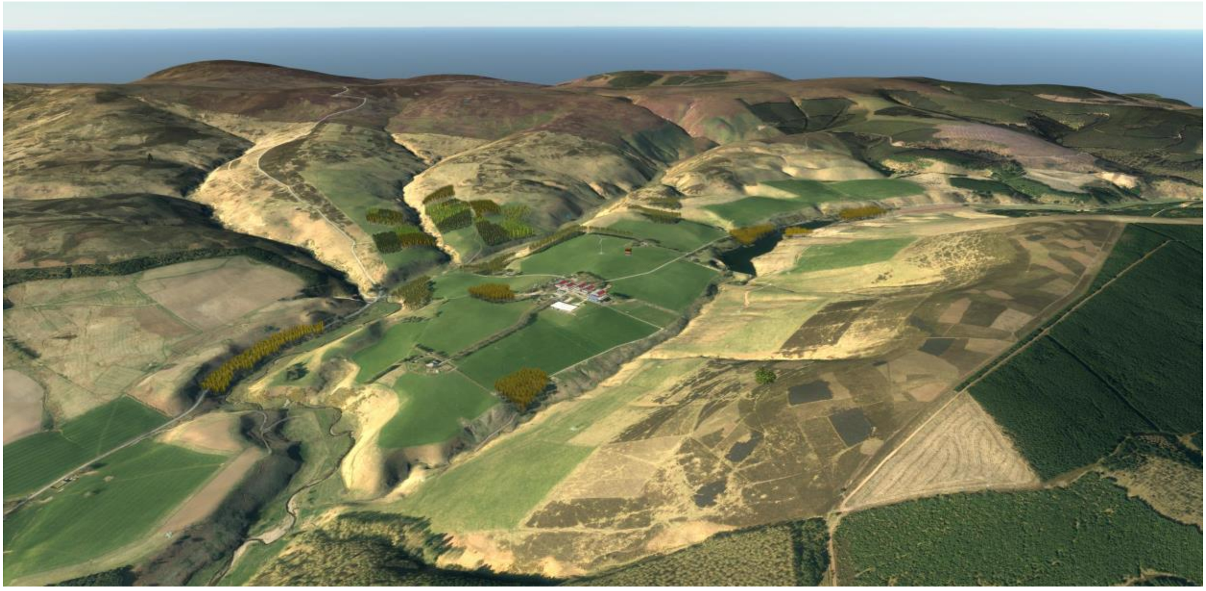

Figure 2 3D Model of Glensaugh including Agroforestry Site

2.3 Simulation of future scenarios of woodland expansion

Forests and woodlands offer many benefits, including timber, food, carbon storage, mitigation of flood and soil erosion, biodiversity habitats, water quality and flow regulation, shelter for livestock and recreation. Forest expansion is a major SG policy objective and instrumental for achieving the zero-carbon target in Scotland by 2045.

Spatial Multi-criteria Analysis (sMCA) has been applied to decide scenarios for spatial targeting of woodland planting by combining the three analyses below:

i. Where the carbon gains would be positive, given the soil type (and the related carbon losses due to planting) and species used.
ii. Where it is economically best to plant. The output is for timber and carbon combined.
iii. Riparian habitat that overlaps the two above.

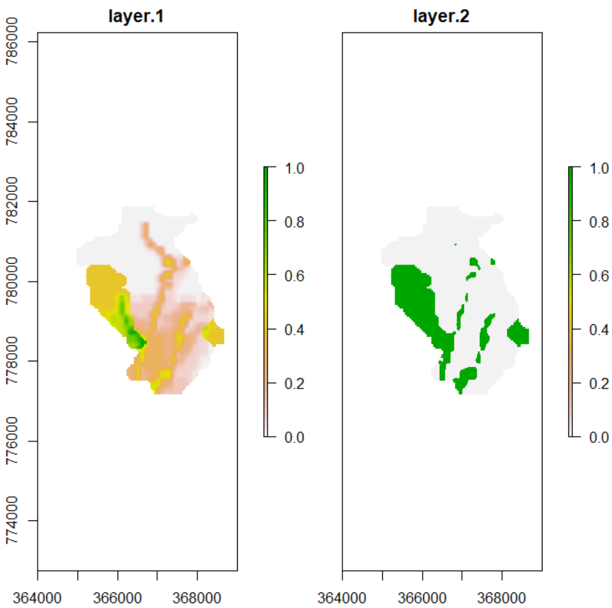

Figure 3 Worst to Best area for planting new woodland in Glensaugh

In **Figure 3**, Layer 1 indicated the cells scored form 'worst to best (0-1) for tree planting. Layer 2 represented the best area for tree planting with top quartile values highlighted.

2.4 Integrated Forest and Climate data visualisation

Dealing with the complexity of data analysis, enabling rapid interpretation and investigating how data could be accessed, visualised and use for decision making to provide benefit for policy makers, businesses, communities and individuals.
New forestry compartments have been imported into the model as the GIS layers. They are visualised by using feature themes which allows users to colorize objects based on their properties or attribution. They also include a legend to understand the model data at a glance. The new woodland categories and their cover percentages in Glensaugh have been presented in 3D pie chart.
The base station has been installed with the sensors set up beside the wind turbine at the Glensaugh farm which can monitor and capture the climate data. Climate data are visualised through 3D responsive bar chart with animation between values.
We have linked both Forest and Climate data with the Glensaugh VR model which is used to deliver expected impacts of attractive and easily understandable information.

3. Results

Two future scenarios of woodland expansions were created (**Figure 4 and 5**). The new woodlands plantation has been represented in Virtual Reality with different tree species and ages, and tree planting densities.

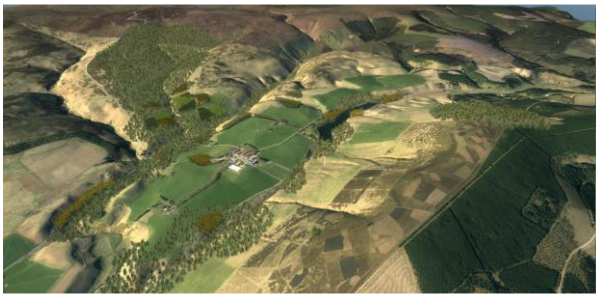

Figure 4 Native Scenario with Scots pines and Birch

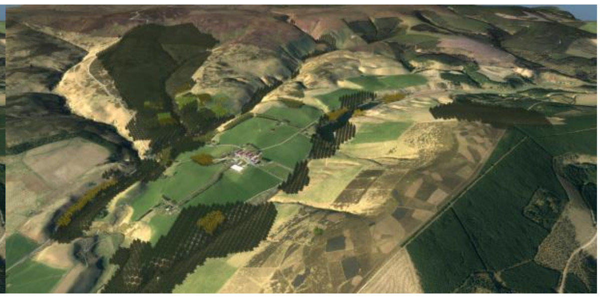

Figure 5 Commercial Scenario with Sitka spruce

Figure 6 shows the new woodland categories and their cover percentages in Glensaugh with the majority of conifer and different soil layers and monthly average soil temperature (June to September 2021) in Glensaugh base station.

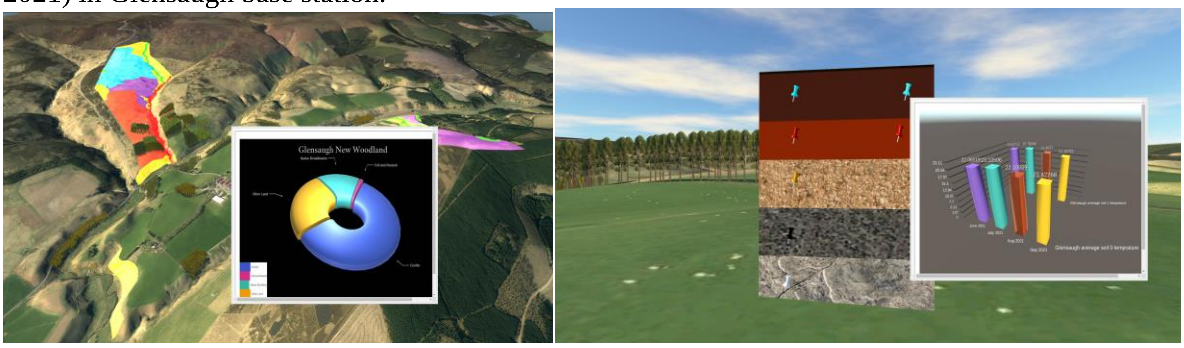

Figure 6 Data visualisation for new forestry compartments and soil temperatures.

The 3D model with simulation of woodland expansion and forest and climate data visualisation was used at the STFC workshop 2021 and Hutton Research Symposium 2021. Audience feedback suggested it has potential implications for the planning of future woodland and interactive data visualisation to increase the effectiveness of their use and contribution to wider sustainable ecosystems.

4. Conclusion

In this paper, an integrated 3D GIS and VR model for scenarios modeling and data visualisation has been developed. Spatial Multi-criteria Analysis has been applied to decide where to plant new woodlands, recognizing a range of land-use objectives while acknowledging concerns about possible conflicts with other uses of the land. The virtual contents (e.g., forest spatial datasets, soil related time series datasets) have been embedded in the virtual landscape model which help raise public awareness of changes in rural areas. Audience feedback indicates this method has a potential impact on future woodland planning and enables rapid interpretation of forest and climate data.

5. Acknowledgements

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Biographies

Dr Chen Wang is a Landscape and visualisation scientist at the James Hutton Institute, working on representation of spatial information and land use scenarios in virtual and augmented reality. His research interests focus on Integration of modelling and virtual reality to present and evaluate farm-scale future scenarios of woodland expansion, Immersive and Collaborative Data Visualisation in VR/AR, integrating virtual environment with remote sensing and GIS for land use, urban flood risk analysis by use of digital and 3D Visualisation technology.

Dr Alessandro is a spatial ecologist and a geographer with experience of both terrestrial and aquatic systems. He uses mechanistic and statistical modelling, as well as GIS and remote sensing technology, to answer research questions.

Professor David Miller is the Knowledge Exchange Coordinator at the James Hutton Institute, leading engagement with UK and Scottish Government, EU policy teams, and public outreach. His background is in spatial modelling and remote sensing, with 32 years' experience the development and application of tools for monitoring rural and urban land use, and assessing impacts of change.

Dr Mark Wilkinson is a senior research scientist in catchment hydrology. His research focuses on the use of Nature-Based Solutions (NBS) for mitigating and adapting to hydrological impacts of extreme events.

Dr Paola Ovando is an environmental economist whose research expertise and interest focus on economic valuation of ecosystem services and natural capital, and their integration into ecosystem accounting and economic decision analysis frameworks, and the development of integrated economic and environmental models to better understand land use and management decisions, and the trade-offs and synergies in the provision of private and public good and services involved.

Bethany Wilkins is a GIS analyst and research assistant at the James Hutton Institute. Her research interests include the utilisation of GIS and remote sensing products for environmental monitoring and investigation of climate change adaptations.

Dr Yang Jiang is a senior lecturer at Robert Gordon University. Her research interests are predominantly 3D visualisations, immersive technologies, computer gaming and computer-generated 3D character animations, as well as real-time motion capture.