EVALUATING NEURAL RELIEF SHADING ACROSS ALBERTA'S PHYSIOGRAPHIC GRADIENT UNDER VARYING SCALE, TERRAIN, AND PARAMETER CONDITIONS

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Introduction

Neural relief shading has become increasingly important in cartography because it can reproduce some of the design qualities of manual Swiss-style relief shading (Hurni et al. 2025) while remaining efficient enough for practical map production. Jenny et al. (2021) demonstrated that neural networks can learn key relief-shading principles, including selective detail reduction, local adjustment of illumination, and the visual emphasis of larger landforms. Eduard application and AI-driven technology (2025) operationalize that research in a usable platform for cartographers, making it possible to test how parameter settings influence the appearance and readability of shaded relief in different types of terrain.

The province of Alberta in western Canada provides an excellent case study because it contains a pronounced physiographic gradient, including Rocky Mountain alpine terrain, foothills, lower mountains, dissected badlands and plains, broad low-relief agricultural plains, and subdued northern lowlands. This diversity allows a single province to serve as a controlled yet varied testbed for terrain-specific hillshading strategies. Alberta therefore offers an appropriate regional framework for evaluating whether a neural approach performs consistently across strongly contrasting landform settings.

The central aim of this study is to evaluate how Eduard-based neural hillshading performs across contrasting Alberta landscapes at three map scales and to identify parameter combinations that improve landform legibility, visual naturalness, and scale appropriateness. More specifically, the study examines how terrain type, generalization settings, aerial perspective, contrast, and DEM resolution interact in the production of readable and visually convincing shaded relief. In doing so, it seeks to advance beyond informal experimentation by establishing a more systematic and reproducible framework for neural hillshade design in support of applied cartographic production.

Method and Tools

Manual relief shading (Imhof, 1982) involves sophisticated design choices that analytical methods often fail to reproduce, including selective simplification, contextsensitive illumination, scale-dependent contrast, and the emphasis of major landforms over minor terrain noise. Although analytical hillshading methods (Burrough and McDonnell, 1998) are efficient, they tend to produce uniform and overly literal representations of terrain, lacking the interpretive quality of expert manual relief. Jenny et al. (2021) frame this limitation as a shift from refining analytical formulas toward learned cartographic style transfer. Building on this direction, researchers from Monash University and ETH Zurich developed Eduard (2025), a commercial AI system for Swiss-style relief shading.

Eduard uses convolutional neural networks (CNNs) for image-to-image translation, learning from paired DEMs and expertly hand-shaded Swiss relief maps. In doing so, it captures cartographic conventions such as ridge sharpening, valley softening, tonal modulation, contrast control, and scale-dependent generalization across reference maps from 1:25,000 to 1:1,000,000. Data augmentation, perceptually oriented loss functions, physiographic diversity, and iterative evaluation with expert cartographers further improved its realism and generalization. Eduard's documentation (2025) also emphasizes that effective shading adjustment requires experimentation, as optimal settings vary with shading style, terrain type, and DEM resolution. In response, this study conducts a formal parameter-sensitivity analysis across two DEM resolutions and three target scales in diverse landforms to identify which settings perform best under different terrain and scale conditions.

This study develops a reproducible comparison of how Eduard parameters, DEM resolution, and map scale affect terrain legibility across contrasting Alberta landforms. Six study areas (Figure 1) were clipped to consistent 50 km × 50 km windows and prepared at both 10 m × 10 m and 100 m × 100 m resolution. The design explicitly tests how native and generalized elevation surfaces behave at 1:50,000, 1:250,000, and 1:500,000. The practical outcome of this work is intended to serve as a set of terrain-specific recommendations for neural hillshading in alpine, foothill, low-mountain, incised plain, and flat landscapes.

The design approach began with a baseline shading for each study area at each scale, after which one parameter group was varied at a time: first shading style, then generalization, then terrain type, followed by aerial perspective, and finally contrast or curve adjustment. This sequential design makes it possible to isolate the visual effects of individual settings while still allowing comparison across terrain classes. Because the same six 50 km × 50 km windows were prepared in both 10 m and 100 m form, paired outputs could also be compared to determine how DEM resolution alone influences the appearance of each terrain class. This structure supports both intra-site and inter-site comparison and helps distinguish scale effects from terrain effects.

Results

The hillshading products generated for the six study sites under varying scale, terrain, and parameter conditions were evaluated against three criteria: landform legibility, visual naturalness, and scale appropriateness. Landform legibility refers to whether major ridges, valleys, dissected surfaces, and subtle plains relief are easy to read. Visual naturalness refers to whether the shading appears convincing and cartographically coherent rather than mechanically over-processed. Scale appropriateness refers to whether the amount of visible detail matches the intended map scale and avoids either unnecessary noise or excessive generalization.

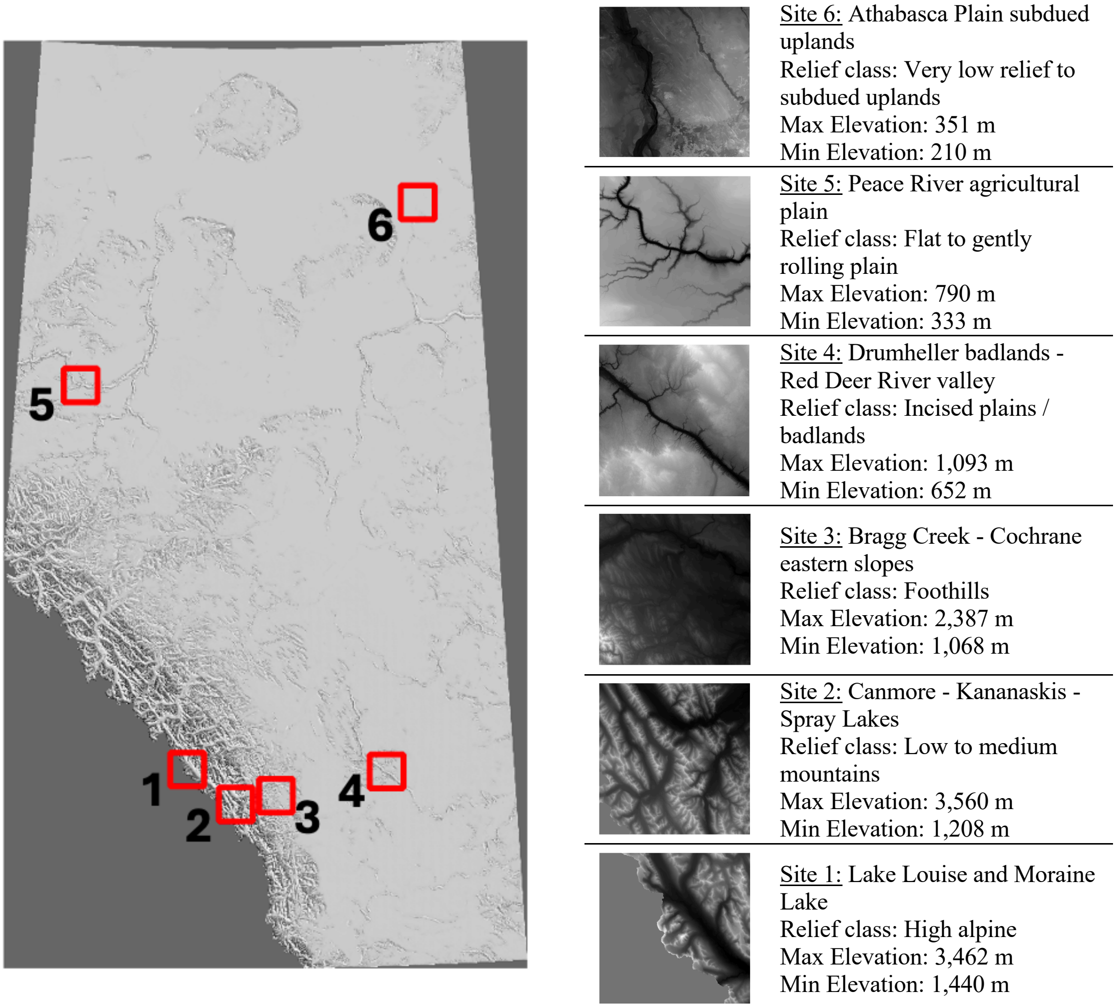

Figure 1: The six sites in the province of Alberta, Canada (approx. scale 1:10M) considered in this study. Each site covers an area of 50 km × 50 km. DEM thumbnails, relief classes, and elevation ranges are shown for each site.

An evaluation panel of cartographers, GIS analysts, and graduate students compared outputs across study sites and parameter combinations to identify terrain-specific patterns in perceived legibility, naturalness, and scale appropriateness. The assessment was intended as an exploratory qualitative evaluation rather than a definitive validation of Eduard settings, and its conclusions should therefore be interpreted as preliminary. Future study will employ a larger and more diverse panel, structured rating protocols, and measures of inter-rater agreement to test the robustness and broader applicability of the proposed recommendations.

The extended version of this article (Stefanakis, 2026) presents a series of illustrations showing hillshading products for the six study areas under different parameter values. It also provides a corresponding set of guidelines explaining how Eduard terrain-type, generalization, and aerial-perspective settings interact with native 10 m and resampled 100 m DEMs across 1:50,000, 1:250,000, and 1:500,000 mapping scales. These comparisons were intended to clarify how parameter choices affect relief legibility in contrasting Alberta landscapes and to identify which combinations are most appropriate for mountain, foothill, badland, and low-relief terrain.

Specifically, findings showed that effective neural relief shading depends on the interaction of terrain ruggedness, map scale, DEM resolution, and parameter selection. At 1:50,000, the 10 m DEM with Large shading performed best, with terrain-type and aerial-perspective values decreasing as relief diminished. At 1:250,000, Macro generalization improved broader structure when using the 10 m DEM but often reduced legibility and naturalness with the already generalized 100 m DEM. Micro generalization controlled badland clutter. At 1:500,000, the 100m DEM with Small shading was most robust, while Flat Area Detail improved subdued plains and low-relief terrain without excessive texture or visual clutter.

Discussion

The main contribution of this study is the development of a reproducible, terrain-specific, and scale-aware framework for applying neural hillshading in a regional case study. Rather than presenting AI-generated relief shading as universally applicable, the study demonstrates that its performance depends on the interaction of terrain character, DEM resolution, and cartographic scale. This is especially relevant to practical cartography, where successful visual outcomes rely not only on the algorithm, but also on careful parameter selection and scale-sensitive design.

Specifically, the study provides: (1) terrain-specific recommendations for Alberta landscapes; (2) evidence of how native 10 m and resampled 100 m DEMs interact with map scale and neural hillshading parameters; and (3) a practical workflow for cartographers selecting settings for mountain, foothill, badland, and flat terrain. In this respect, it bridges methodological experimentation and applied cartographic production.

The study also highlights broader implications for machine learning in terrain representation. Systematic evaluation across physiographic gradients may enable the development of regionalized best practices, reducing reliance on models trained exclusively on Swiss relief. Alberta's strong physiographic contrasts make it an effective testing ground for this question. The findings therefore contribute not only to the practical use of Eduard, but also to broader discussions of transferability, generalization, and cartographic interpretation in AI-based terrain visualization.

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