

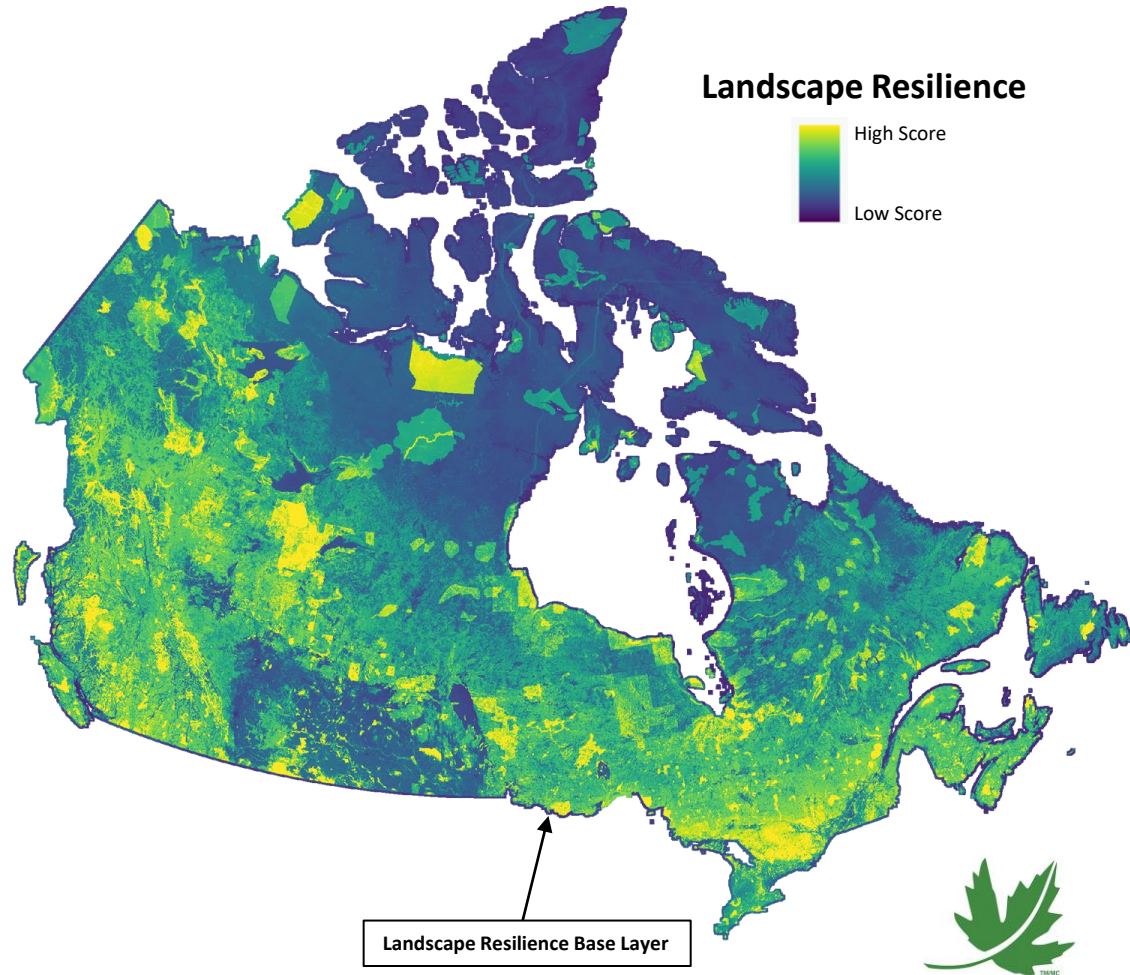
# LANDSCAPE RESILIENCE; CONCEPTS, SCORE & BASE LAYER OVERVIEW

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# Objectives

- To provide an introduction on **Landscape Resilience** (why, what, how, and use case).
- To overview the spatial data and equation used to generate the **Landscape Resilience Score** and **Base Layer**.



# Why Landscape Resilience?

- To **quantify** Canada's landscape using a **single metric**.
- To increase planning efficiency with a **centralized** approach.
- To align conservation efforts with the [strategic plan](#) (optimize delivery and accelerate conservation) and **evaluate impact**.
- To link **C**onnectivity, **A**dequacy, **R**epresentatives and **E**fficiency principles to the landscape ([C.A.R.E.](#)).
- To provide basis for directing **limited resources** to those areas on the landscape where they are likely to have the **greatest benefit**.



# What is Landscape Resilience?

- **Landscape Resilience\*** is an area of land marked with the combination of biodiversity and diverse, connected habitat that enables species to persist and adapt to environmental pressures over time.
- **Landscape Resilience Score** is the result of combining **ecological variables** that address **protection**, **biodiversity**, **connectivity**, **climate**, **habitat**, and **threats** at the landscape scale.
- NCC measures Landscape Resilience at the **1km x 1km** pixel scale using the Landscape Resilience **Score**. Each pixel makes up the Landscape Resilience **Base Layer**.
- \* NCC's **interpretation** of resilience. See appendix and reference slides for academic literature definitions.



# How will Landscape Resilience be Used?

To support **landscape scale** conservation planning

- To set priorities at the **Canada-wide** scale and provide a **case for conservation**.
- To help identify unprotected resilient areas as **candidates** for **area-based conservation**.
- To help identify degraded areas as **candidates** for **restoration**.
- To **quantify** a projects contribution to **increasing** Landscape Resilience.

**Areas** with high Landscape Resilience **Scores** implies **protection**, **biodiversity**, **connectivity** **climate** and **habitat** are well **met** with minimized **threats**.



# What Drives Landscape Resilience?

## Themes

## Variables

Protection:

existing conservation

Biodiversity:

richness, adequacy, key biodiversity areas, SAR critical habitat

Climate:

centrality, refugia

Connectivity:

current density

Habitat:

forest, wetland, grassland, rivers, shoreline

Threats:

human disturbance, climate extremes



# Landscape Resilience Inputs

## Protection

- Protected areas contribute to Landscape Resilience by **safeguarding** species from threats of biodiversity loss.

### Variables that capture Protection:

- **Existing conservation** from [Canadian Protected and Conserved Areas Database](#)
- This includes NCC fee simple and conservation agreement achievements not in CPCAD
- All protected area classes are considered equal



# Landscape Resilience Inputs

## Biodiversity

- Biodiversity theme is captured by mapping species richness and calculating protection goals for each species. Individual goals are then summed into a single cumulative **adequacy goal**.
- The cumulative adequacy goal explains the required protection needed to ensure species **persistence** throughout time; where some species need more conservation than others ([Rodrigues et al, 2004](#)).

### Variables that capture Biodiversity:

- **Species at risk**: richness & cumulative adequacy goal ([ECCC](#))
- **Endemic species**: richness & cumulative adequacy goal (NSC)
- **Common species**: richness & cumulative adequacy goal (IUCN & NSC)
- **Key biodiversity areas** ([KBA Canada](#) & [Birds Canada](#))
- **SAR Critical habitat for species at risk** ([ECCC](#))





# Landscape Resilience Inputs

## Climate

- Related to **connectivity**, it is important to adjust for the effects of climate change and give species the opportunity to move as climate conditions change.
- Many species will be facing conditions beyond their ability to survive by 2100 and will need to **shift** to more suitable environments to **persist** (Karen et al, 2023)

### Variables that capture Climate:

- **Climate refugia** (Stralberg et al. 2021; [AdaptWest](#))
  - Locations with rare climatic conditions that are likely to facilitate species persistence under climate change
- **Climate centrality** (Carroll et al. 2018; [AdaptWest](#))
  - Represents connectivity between current and future climate analogs



# Landscape Resilience Inputs

## Connectivity

- Landscapes that are connected promote the **movement** of species among habitat patches
- High connectivity values favor **biological flows** and represent movement and dispersal patterns of species.

### Variables that capture Connectivity:

- **Current density** ([Pither et al, 2023](#))
  - Considered anthropogenic and natural features and their known effects on the movement of terrestrial non-volant fauna to predict connectivity.



# Landscape Resilience Inputs

## Habitat

- By securing a **diverse portfolio** of habitat types ensures redundancy is built into the protected area network.
- Habitat types reflect NCC impact metrics.

### Variables that capture Habitat:

- **Forest landcover** hectares ([VLCE2](#) and [AFFC LUTS](#))
- **Wetland** hectares ([CanVec](#))
- **Grassland** hectares ([AAFC LU](#))
- **Rivers** kilometers ([NRCan](#))
- **Shoreline** kilometers ([CanVec](#))



# Landscape Resilience Inputs

## Threats

- Habitat pressures pose a **negative impact** on Landscape Resilience.

### Variables that capture Threats:

- **Human footprint index** ([Hirish-Pearson et al, 2021](#))
  - considers built environments, population density, nighttime lights, crop lands, pasture lands, forestry, railways, roads dams, reservoirs, navigable waterways, mining and oil and gas disturbances.
- **Climate extremes** ([La Sorte et al. 2021](#))
  - Useful way to capture extreme stressors on biodiversity



# Landscape Resilience Equation

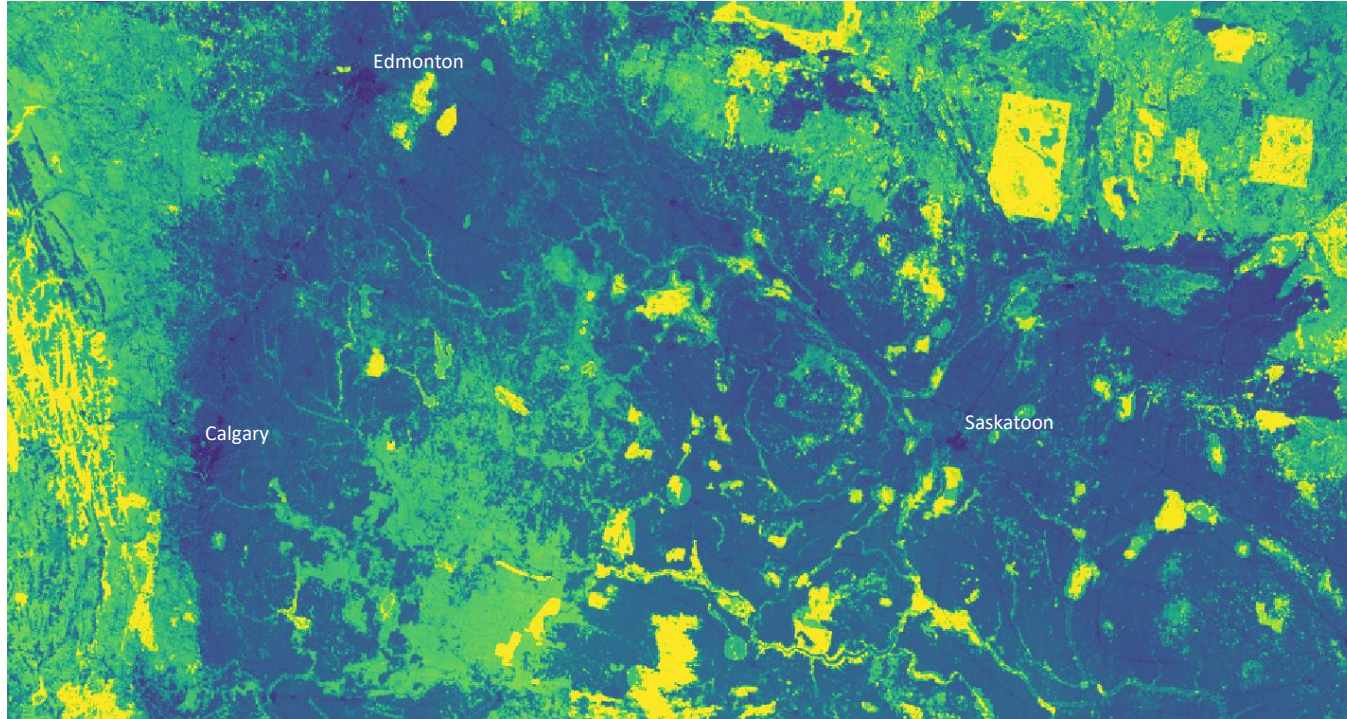
Landscape Resilience Score =

$$\begin{aligned} &\text{protection} + \\ &\text{key biodiversity areas} + \text{SAR critical habitat} + \text{SAR richness} + \text{END richness} + \\ &\text{common richness} + \text{SAR goal} + \text{END goal} + \text{common goal} + \\ &\text{connectivity} + \\ &\text{climate centrality} + \text{climate refugia} + \\ &\text{forest landcover} + \text{wetland} + \text{grassland} + \text{rivers} + \text{shoreline} \\ &- \text{human footprint index} - \text{climate extremes} \end{aligned}$$

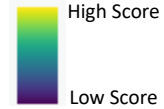
CP&P **recommends** all variables to be **equal** (no weights).



# Landscape Resilience Output



## Landscape Resilience



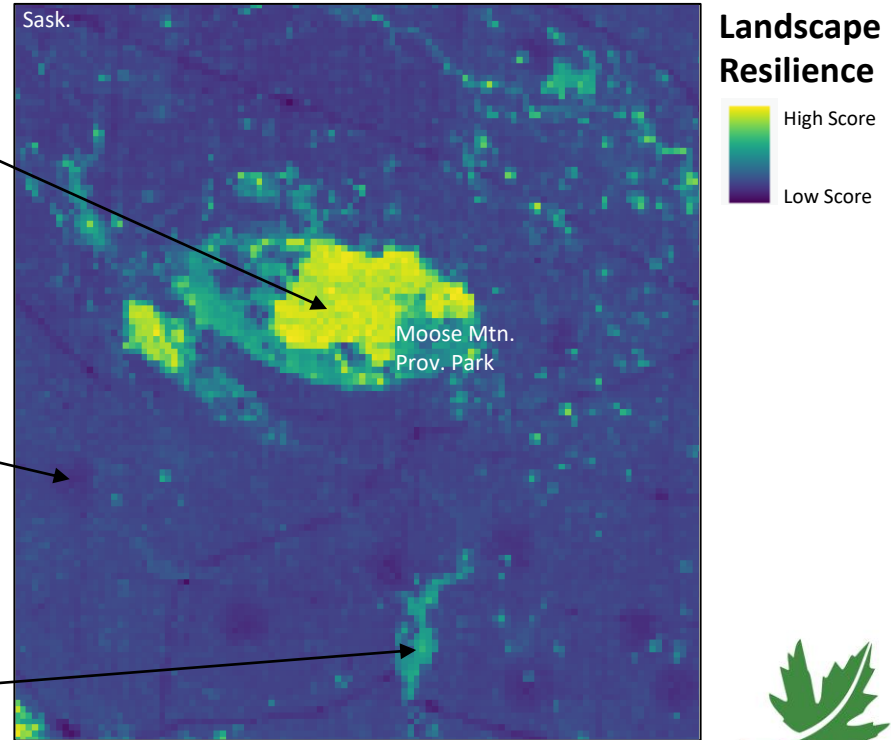
Each pixel has a **score**.

All pixels make up the **base layer**.



# Output Interpretation

- An area that has a **high** Landscape Resilience **Score** is **protected**, with a varied combination of **biodiversity**, **connectivity** **climate** and **habitat** with minimized **threats**.
- An area with a **low** Landscape Resilience **Score** is **unprotected**, with a varied combination of low biodiversity, unconnected, poor climate resilience and limited and threatened habitat.
- Protecting intact areas with moderate Scores will improve **Landscape Resilience**.



# Limitations

- **Ambiguity** in definitions and lack of quantification
- Omitting the comparison between current landscape to a **historical range of variation**
- Omitting **threshold definitions** that indicate when a landscape loses ecological memory
- No data to support **habitat attributes** such as a quality
- Difficult to capture small area-based conservation's contribution to Landscape Resilience when **rolled-up** to the 1km scale
- Difficult to capture site-level reclamation project's contribution to Landscape Resilience when **rolled-up** to the 1km scale
- No **temporal** analysis post reclamation
- Variable selection was based on "**expert**" **opinion** (no statistically significant testing)
- No **ground truthing** of base layer (could not find real world sites?)
- Omitting **ecological resilience** concept in terms of disturbance and bounce-back





# Appendix

## Landscape Resilience - What's in the academic literature?

- For a **landscape** to be **resilient**, it must be able to **adapt** to pressures over time in a way that supports the **long-term survival** of biodiversity and ecosystems.
- Landscape Resilience retains “**ecological memory**” & **connectivity** among neighboring systems post disturbance; avoiding regime shifts at broad spatial extents.
- **Ecological Resilience** is the main term, followed by other variations (ex. spatial resilience).
- When the **resilience** of an ecological system is **exceeded**, ecosystems enter a **new** local equilibrium that differs in **structure** and **function** from the previous state (Craig et al, 2016).
- **Resilience** is the ability to **recover** once a disturbance ends. **Resistance** is the ability to persist or **withstand** a disturbance (Strickler, 2022).



# Appendix

## Landscape Resilience Score Details:

Each variable is **scaled** between **0** and **1** before the score is executed. This step is required to combine features that have different units of measurement.

### Scaling equation:

Normalized feature = (feature – min value) / ( max value – min value)



# References

Resilience and stability of ecological systems:

<https://www.annualreviews.org/doi/abs/10.1146/annurev.es.04.110173.000245>

Metrics and Models for Quantifying Ecological Resilience at Landscape Scales:

<https://www.frontiersin.org/articles/10.3389/fevo.2019.00440/full>

Wild, connected, and diverse: building a more resilient system of protected areas:

<https://esajournals.onlinelibrary.wiley.com/doi/full/10.1002/eap.1527>

Understanding protected area resilience: a multi-scale, social-ecological approach:

[https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/13-2113.1?casa\\_token=a5GUcC01mnsAAAA:dsV4tSiXnHfhPwnCutvAEma-FGFrXO40JND730ft-nI6Oq\\_Eqe6GlarmszasTqznSmhyP1B2BW-0UNNg5](https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/13-2113.1?casa_token=a5GUcC01mnsAAAA:dsV4tSiXnHfhPwnCutvAEma-FGFrXO40JND730ft-nI6Oq_Eqe6GlarmszasTqznSmhyP1B2BW-0UNNg5)

Landscape ecological concepts in planning: review of recent developments:

<https://link.springer.com/article/10.1007/s10980-021-01193-y>

Managing Rather Than Avoiding “Difficulties” in Building Landscape Resilience:

<https://www.mdpi.com/2071-1050/13/5/2629>

Quantifying spatial resilience:

<https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.12634>

Resilience in the Studies of Biodiversity-Ecosystem Functioning:

[https://www.cell.com/trends/ecology-evolution/fulltext/S0169-5347\(15\)00321-3](https://www.cell.com/trends/ecology-evolution/fulltext/S0169-5347(15)00321-3)

Perspectives for ecosystem management based on ecosystem resilience and ecological thresholds against multiple and stochastic disturbances:

<https://www.sciencedirect.com/science/article/pii/S1470160X15002411>

A riparian conservation network for ecological resilience:

<https://www.sciencedirect.com/science/article/pii/S0006320715002529#bb0155>

A resilient and connected network of sites to sustain biodiversity under a changing climate

<https://www.pnas.org/doi/10.1073/pnas.2204434119>

Biodiversity, ecosystem function, and resilience: ten guiding principles for commodity production landscapes

[https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/1540-9295%282006%29004%5B0080%3ABEFART%5D2.0.CO%3B2?casa\\_token=iSM4aLrMYhcAAAA%3A7vbR7SrZmxu\\_f3k5FDiNeRWU9icdsIW24OMs6uA9QyAp6uCxU-JlKypg2ox7W9UpNIh2NCDROQtXkV4I](https://esajournals.onlinelibrary.wiley.com/doi/full/10.1890/1540-9295%282006%29004%5B0080%3ABEFART%5D2.0.CO%3B2?casa_token=iSM4aLrMYhcAAAA%3A7vbR7SrZmxu_f3k5FDiNeRWU9icdsIW24OMs6uA9QyAp6uCxU-JlKypg2ox7W9UpNIh2NCDROQtXkV4I)

Ecological Resilience and Resistance

<https://www.thesciencewriter.org/resilience-stories/ecological-resilience-and-resistance>

Enabling a National Program for Ecological Corridors in Canada

[Enabling a National Program for Ecological Corridors in Canada in support of biodiversity conservation, climate change adaptation, and Indigenous leadership – ScienceDirect](#)





# LANDSCAPE RESILIENCE BUILDER

**THIS IS NOT THE LANDSCAPE RESILIENCE TOOL**

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# Landscape Resilience Builder

- Designed as an **engagement** tool that shows transparency in the make-up of the Landscape Resilience (LR) Score.
- Provides a **proto-type** of Landscape Resilience, where each **pixel** has a score
- Users can **change** values and update the **LR score** in real time. This provides a means to reason with the relative importance of layers that comprise the score. **Note:** CP&P Recommends all weights are equal and set at 1.
- [Go to Builder](#)



# Landscape Resilience Builder

## LANDSCAPE RESILIENCE BUILDER

**Biodiversity**

**Key Biodiversity Areas**

Species at Risk, Critical Habitat: 1

Species at Risk, Richness: 1

Endemic Species, Richness: 1

Common Species, Richness: 1

Species at Risk, Goal: 1

Endemic Species, Goal: 1

Common Species, Goal: 1

**Connectivity**

Connectivity: 1

**Climate**

Refugia: 1

Centrality: 1

**Habitat**

**Forest**: 1

**Grassland**: 1

**Wetland**: 1

**Rivers**: 1

**Shoreline**: 1

**Protection**

Existing Conservation: 1

**Threats**

Human Footprint Index: 1

Climate Extremes: 1

**RESET VALUES** **UPDATE SCORE**

**DOWNLOAD SCORE** (Download score (.tif) and values (.xlsx))

**PowerPoint**

**Web link**

**Update values**

**View layers one at a time**

**Toggle overlays**

**Legend**

**Landscape Resilience Equation**

**Click points to view LR Score**

- ☒ Landscape Resilience
- ☐ Critical Habitat
- ☐ SAR Richness
- ☐ END Richness
- ☐ Common Richness
- ☐ SAR Goal
- ☐ END Goal
- ☐ Common Goal
- ☐ Connectivity
- ☐ Climate Refugia
- ☐ Climate Centrality
- ☐ Forest
- ☐ Grassland
- ☐ Wetland
- ☐ Rivers
- ☐ Human Footprint
- ☐ Climate Extremes
- ☐ Off
- ☐ Protected
- ☐ KBA
- ☐ LR Score

**Landscape Resilience Score:**

$$(KBA * 1) + (critical\ habitat * 1) + (SAR\ richness * 1) + (END\ richness * 1) + (common\ richness * 1) + (SAR\ goal * 1) + (END\ goal * 1) + (common\ goal * 1) + (climate\ refugia * 1) + (climate\ centrality * 1) + (connectivity * 1) + (forest * 1) + (grassland * 1) + (wetland * 1) + (rivers * 1) + (shoreline * 1) + (existing\ conservation * 1) - (human\ footprint * 1) - (climate\ extremes * 1)$$

**Reset values** **Update score on map**