Prospectivity methodology for regional CO_2 storage potential

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Summary

Typically, studies evaluating regional CO_2 storage potential focus on capacity, with insufficient emphasis on characterizing containment, injectivity, or monitorability, all critical factors in the ultimate success of a storage project (e.g. Bachu, 2008; IPCC, 2005; IEA, 2022). Our reanalysis of storage resources involves moving towards an assessment of ‘prospectivity’, which combines storage capacity with different layers representing regulatory, economic, risk, and other factors. This methodology can be applied to a variety of storage options, including CO_2 enhanced oil recovery, depleted oil and gas reservoirs, and saline aquifers. Prospectivity mapping allows us to identify areas with the highest potential within a given storage option as well as to find the most prospective option for storage in a given region.

We present results of prospectivity mapping for multiple deep saline aquifers in the Western Canada Sedimentary Basin, including relative prospectivity analyses which compare one storage option to another in a given location. These results provide the basis for further studies on the optimal management of the regional-scale pore space resource, simulations of plume interactions from neighbouring projects in a given region, and a guide towards more local-scale site selection and characterization.

Methodology

To characterize more holistically the most suitable areas to store CO_2, we produce maps of a prospectivity index by taking assessed capacity and adding in various data layers that modify capacity and relate to risk or economic factors (Figure 1). The layers that we combine include a measure of source proximity, reservoir and seal thicknesses, permeability, legacy well density to identify potential leakage pathways, and depth, among others. All layers are then normalized and combined by a weighted summation. The weights can be modified slightly to control the relative importance of different layers and in that way we create prospectivity with a particular emphasis on either risk mitigation (where layers like seal thickness contribute more), cost reduction (where layers like depth and source proximity are weighted more), or practical capacity (where the capacity and permeability layers contribute more). Once we perform the prospectivity analysis on multiple storage options, we can start comparing them in a relative sense.

The process of computing prospectivity as a combination of different attributes to try to characterize storage suitability is a type of what is called multi-criteria decision making analysis. Weighted summation is the simplest type of this analysis and equates to adding up pros and cons. In these simple cases the weights come from pure judgement or by asking experts (e.g. Wendt et al., 2022). There are also more sophisticated multi-criteria decision making methods that have been applied to assessing CO_2 storage in other parts of the world, in particular methods that determine the weights mathematically, such as an Analytical Hierarchy Process (AHP, e.g. Llamas and Cienfuegos, 2012), Analytical Network Process (ANP, e.g. Hsu et al., 20212) or the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS, e.g. Alcalde et al., 2021).

We are looking to other parts of the world to guide our weighting scheme, while still ensuring that the weights reflect our local set of circumstances in Alberta. To understand the influence of different weighting schemes, the weights can also be modified systematically as part of a sensitivity analysis.

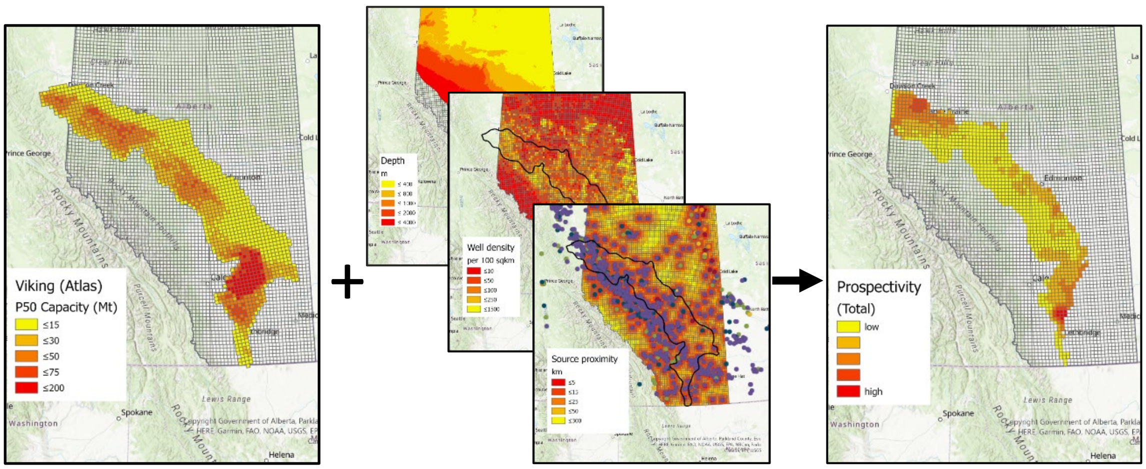

Figure 1. Illustration of the process for computing prospectivity for CO_2 storage in a saline aquifer as a combination of storage capacity and various data layers related to economics and risk.

Results

Figure 2 shows an example of a small region where two different aquifers both have storage potential, helping to identify which aquifer is more prospective than the other in different areas. Where the more orange colours dominate, aquifer 1 has higher prospectivity, and where the blues dominate, aquifer 2 has higher prospectivity. Where the deep green colour is present, both aquifers have high prospectivity. Having multiple good options for storage in a given area has been identified as a de-risking factor for development so these are important areas to identify (e.g. IEA, 2022). These areas may also be good candidates for stacked storage, where CO_2 is stored simultaneously in multiple formations, in order to maximize the available storage in a given area.

Figure 3 is an example of analysing the sensitivity of the prospectivity mapping to the underlying weights. In this example we are varying how much the risk-related layers contribute to the prospectivity index, from one third of the total with capacity and economics also contributing a third each shown top left, up to 90% importance assigned to risk reduction, 5% each to the other two in the bottom right. The prospectivity in some areas changes significantly, but there are also areas which remain relatively unchanged. By performing this analysis with all the different layer weights, it becomes apparent that some regions remain low prospectivity no matter the weighting scheme and some regions remain high. This can help guide where to focus future efforts: initially on consistently high-prospectivity areas for more detailed study, and in other more variable-prospectivity areas looking more at what that variability means or where it comes from. High prospectivity areas are likely to be targeted by multiple potential storage projects, meaning that identification of these areas is important to begin studies of how to optimally distribute projects and how to manage interactions between projects that may negatively impact ultimate achievable capacity.

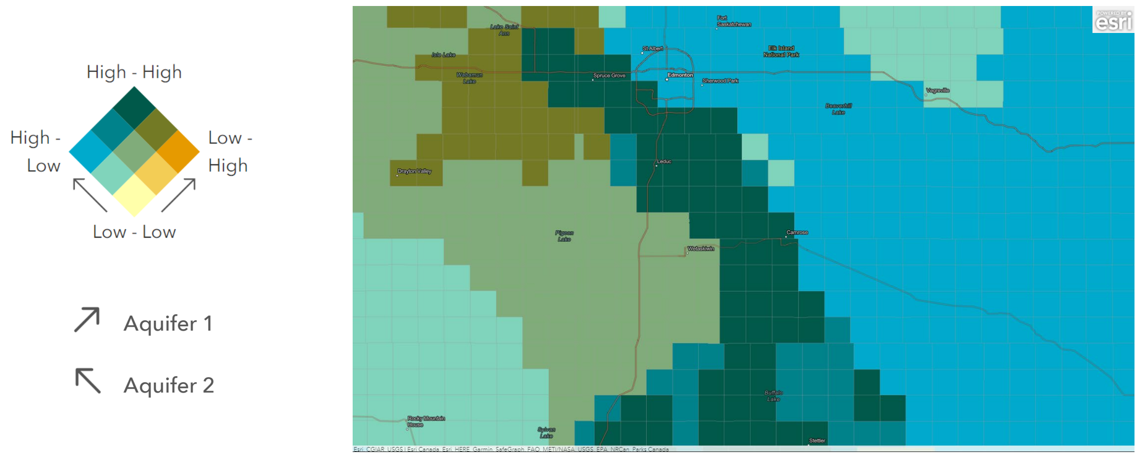

Figure 2. Map of relative prospectivity for two saline aquifers.

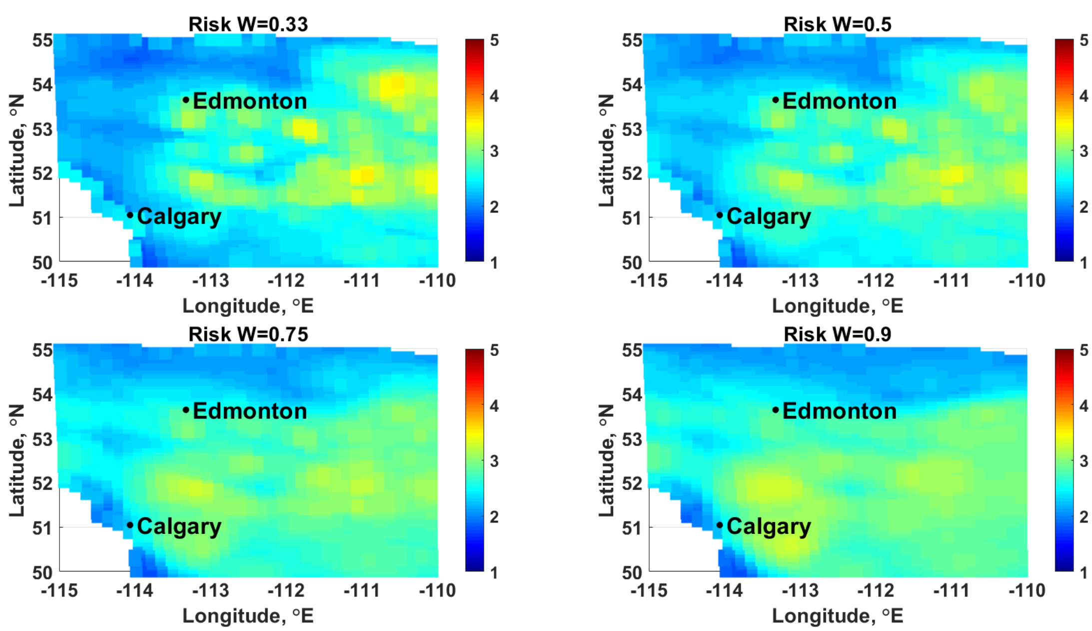

Figure 3. Prospectivity map computed with different weights applied to risk-related attributes, from 0.33 (top left) to 0.9 (bottom right). Colour scale is prospectivity index, from low (1 - blue) to high (5 - red).

Conclusions

Looking at CO_2 storage resources using the concept of prospectivity mapping combines elements related to capacity, containment, and injectivity. The weighting of the layers that go into the prospectivity mapping can be adjusted to emphasize different factors such as economics, risk, and practical capacity. When the analysis has been completed for multiple storage options, those options can then be compared by mapping the prospectivity in a relative sense. By testing sensitivity to the layer weights it is apparent that there are some persistently high prospectivity regions; identification of these areas provides a focus for where to improve underlying data quality and availability, and start looking at how prospectivity changes dynamically as a result of multi-project interactions.

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