Development of an Offset Suitability Index to Prioritize cultivated lands for the SE Alberta Conservation Offset Pilot

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Project:

Quantitative methods for GIS layer calibration and weightings for mapping an Offset suitability and Prioritization Index for the South East Alberta Conservation Offset Pilot Project

This project is part of the development work needed for the SE Alberta Conservation Offset Pilot (SEACOP). The pilot will allow private landowners to contract for conversion of annually seeded land parcels to mixed native grassland. Metrics are needed to prioritize and determine suitability of parcels for conversion.

Objective:

To provide a clear, consistent, objective and defensible method for prioritization of cultivated lands based on expert generated and spatially described criteria.

Process:

This process was led by Dr. Cormack Gates of the University of Alberta. He has been part of other initiatives using this process and guided our team through each of the stages in addition to providing the initial calculation framework. This process uses expert knowledge in addition to available spatial data in a repeatable process to achieve a set of criteria from which we are able to prioritize cultivated lands within the dry mixed grass and mixed grass sub-regions of Alberta. Experts were primarily form the South Saskatchewan region and consisted of wildlife biologists, soil and range management specialists, cropping and soil specialists, grassland ecologists both within government and non- government agencies: Environment and Sustainable Resource Development (ESRD) – Fish and Wildlife, Range Resource Management Program, Alberta Conservation Association(ACA), Alberta Agriculture and Rural Development (AARD) and LandWise Inc. There were three stages to this process followed by a field truthing of the Index to ensure the index outcomes are consistent with what is actually on the site. The GIS analysis and related work was completed by Alberta Agriculture and Rural Development and Environment and Sustainable Resource Development (ESRD) with provision of spatial data by ESRD, Agriculture and Agri-Food Canada (AAFC), AARD and Alberta Biodiversity Monitoring Institute (ABMI).

Development and field truthing stages:

1) ***Workshop:*** experts met to develop list of criteria for selecting and prioritizing conservation offset targets (October 1, 2012, Lethbridge). Maps of the region with spatial data features were used by participants to define potential targets and the reasons (criteria) why these areas were important in their opinion. The list of criteria, expert identified polygons(hand drawn – later digitized)and descriptions were refined during later meetings involving AARD, ESRD and Dr. Cormack Gates. Two categories of map data were identified: ecological criteria and risk criteria. Other factors that are not available as spatial data were also identified. These factors can be used during site assessment when parcels are assessed on the ground.

2) ***Delphi Process:*** An analytical procedure developed to calibrate cut-offs and data ranges for the criteria employing the Delphi method. Individual participants (experts) were asked to identify cut-offs for data ranges for mapped data for levels of suitability (most ideal proximity range) For example from 1 to 9 (excellent to poor). Individual responses were submitted anonymously and were combined to calibrate the criteria. Individual participants are asked to rank their expertise concerning each parameter on a scale of 1 to 9 (very low to very high). The responses were combined to generate univariate statistics (mean, median, standard deviation and coefficient of variance) and used to guide group discussions for consensus on map layer calibration. This required 2 group meetings. Discussions centered on selecting a cut off interval or group of cut off intervals where changes in the coefficient of variation was observed to be the greatest between cut off intervals or groups of cut off intervals. The consensus calibration ratings were used to reclassify map layers into individual discrete 'cost' maps, i.e. map layers.

3) ***Analytical Hierarchy Process (AHP):*** The Analytic Hierarchy Process is used to establish relative weights among map layers. Participants were asked to rank pairwise comparison statements about the criteria (map layers) using a rank scale from 1 to 9 (equally important to extremely more important). This procedure was carried out by individual experts working on their own, avoiding discussion between them. Individual responses were entered into an importance table then solved for relative weights for criteria. The criteria weights calculated from inputs by individual participants were averaged across participants to calculate and map an overall Conservation Benefits Index surface. The detailed index value calculations are Included in Appendix A.

4) ***Field Truthing the Index:***

Methods (Summer 2013): Cultivated land parcels were randomly selected for investigation within the pilot target area, with 15 parcels within each of the low (less than or equal to 0.60), medium (between 0.61 and 0.70) and high eligibility class (greater than 0.70). These 45 sites were mapped with appropriate natural features and infrastructure to facilitate follow up and field investigations.

Best available imagery and GIS datasets were acquired for each site, including the surrounding land areas. This was then used for a desk top exercise to determine current land use compared to the datasets used in the model to determine an index value. The Abacus Database was a very useful for this exercise because it uses recent, high quality imagery and routinely updates infrastructure data.

The imagery was used to identify landscape features and native habitat areas that would have been factored into the index calculation. These include proximity to things like private land irrigation, water bodies or native prairie parcels. Proximity to irrigation infrastructure would have reduced while proximity to native prairie or water bodies would have tended to increase the relative index values for converted sites.

Abacus data helped to identify the types of infrastructure that would factor into a land use intensity calculation – linear features like power, gas or pipe lines, farmsteads or well sites, roads of any type, communication towers and irrigation district infrastructure. Those sites with or proximal to areas with higher land use intensity would tend to have lower index values.

The Abacus Database also proved useful to plan a site visit, given that many of the randomly selected sites were not accessible through the road network.

Google Earth was used to cross-reference the Abacus Database and to provide a broader land use and landscape context for each of the selected cultivated parcels. Google Earth also helped with calculating distances from the parcel in question to other landscape features (for example, native prairie blocks).

Site Visits (Fall 2013): Field trips were conducted to confirm the accuracy for the desk top analysis of imagery and Abacus datasets for the selected parcel and surrounding landscape areas. Notes were made for any discrepancies and if so, their nature. For example, a new powerline had been recently constructed through the pilot area. The majority of the sites were assessed from the edge of the property on grid roads (government road allowances). For sites without grid road access, a vantage site was used with observations confirmed in the office using best available imagery. Only one site prevented access to within one kilometer (site 26) and evaluation was restricted to analysis of imagery and Abacus datasets.

Pictures of each site and surrounding area were taken as a record of the current land use.

Following each site visit, a “subjective rating” of low, medium or high class was assigned for each site by the technician and this was later compared to the modelled index rating.

Summary: Forty five randomly selected cultivated land parcels were examined through a desk-top exercise using GIS datasets and high quality imagery followed by field inspections. Based on that process, seven of the forty-five parcels (16%) were given “subjective ratings” for offset suitability that were different from the model generated OSI ratings. Three of these discrepancies could be explained by a newly constructed power line that transected the parcels in question. Discrepancies for the other four sites may have resulted from other factors affecting the modelled values that were not considered during this analysis, for example, the presence/absence of wildlife corridors or proximity to important features like water bodies or native prairie blocks. Two of those sites were given a higher and two were given a lower subjective rating than modelled values. The two that were lower than expected were likely due to the absence of water bodies and wildlife corridors. The two that were higher than expected were irrigated parcels and while irrigation would likely not be suitable for offset (given the potential higher returns from crop production versus native rangeland), the relatively higher model values could reflect some of the other important attributes. One way to correct this would be to assign parcels with irrigation infrastructure as "low" through an automatic program default.

The OSI modelling approach is a reliable tool for estimating the relative offset suitability for the majority of cultivated land parcels in the SEACOP target area. OSI values are consistent with what would be expected from the 17 parameters considered in the model. They reflect the subjective assessments for the relative offset value based on detailed imagery and GIS data analysis followed by a field inspection. Only four of the 45 sites (9%) had OSI values that disagreed with a subjective assessment. It is recommended that recent high quality imagery along with the Abacus Database be used to make a subjective assessment to confirm that the modelled OSI makes sense when validating potential offset sites. Some adjustments may be required to account for data gaps (for example, new infrastructure) or obvious discrepancies. New model iterations should consider having a default to automatically assign a "low" suitability for land parcels with existing irrigation infrastructure.

For more information on this assessment, please contact Wally Sawchuk at wally.sawchuk@gov.ab.ca

Offsets Target Criteria:

Private, non-native lands: Conservation offset target areas will be restricted to private non-native lands. This is a screening variable and will not be used in calibration or weighting calculations.

Ecological Criteria (calibration and weighting of 17 variables)

1) ***Proximity to native prairie block (NPB):*** Select private lands within or close to large areas of native prairie (blocks). An agreed upon minimum block size was 4 sections. The minimum block size was based on scientific evidence for the threshold for grassland song bird density. Native prairie blocks are predefined and are illustrated on an accompanying map.
2) ***Proximity to Parks and Protected Areas (PPA):*** Select private lands close to parks and protected areas. This includes the following types.
    - Crown Reservation
    - Ecological Reserve
    - Heritage Rangeland

- Natural Area
- Provincial Park

3) ***Proximity to Environmentally Significant Areas (ESA):*** Select private lands within or close to ecologically sensitive areas on both private and public lands that don't necessarily have management protection. Alberta Tourism, Parks and Recreation defines the criteria for ESAs as follows.

CRITERION 1: Areas that contain elements of conservation concern.

CRITERION 2: Areas that contain rare or unique landforms.

CRITERION 3: Areas that contain habitat for focal species.

CRITERION 4: Areas that contain important wildlife habitat.

CRITERION 5: Riparian areas (3 classes).

CRITERION 6: Large natural areas.

CRITERION 7: Sites of recognized significance."

4) ***Proximity to sage-grouse critical habitat areas (C&D1):*** Select private lands within or close to critical areas
5) ***Proximity to movement corridor s (MC):*** Select private lands within or close to expert-defined movement corridors polygons 16, 17 and 18 Four Ways creek, Canal creek, and Ketchum creek.
6) ***Proximity to ungulate winter range (UWR):*** Select private lands within or close to F&W-defined winter ranges for pronghorn, mule and white tail deer.
7) ***Proximity to Lotic "flowing water"(PFW):*** and Overflow GVI sites
8) ***Proximity to Lentic "standing water"(PSW):*** and Sub-irrigated GVI sites
9) ***Proximity to native public land(NPL):*** Select private lands close to native public land (>90% native cover)
10) ***Proximity to native private land(NPR):*** Select private lands close to native private land (>90% native cover)

Landuse/risk Criteria (calibration and weighting)

11) ***Proximity to lands with existing conservation agreements/projects (CAP) :*** Select private lands close to existing conservation projects. Conservation Easements, ACA, NCC (does not include land owned by conservation groups)
12) ***Priority on non-irrigated lands (NIRL)***therefore distance from irrigated lands:
13) ***Land use intensity (LUI), "percent of unit under infrastructure development":*** Select private lands with low % infrastructure development. The Land Use Intensity (LUI) data layer is a hybrid layer. LUI is a combination of selected site type categories from the

Grassland Vegetation Inventory (GVI) and selected Alberta Biodiversity Monitoring Institute (ABMI) Human Footprint (HF) category codes (HumanFootPrintMapABMIGuide.pdf). All of the HF types were used to define LUI with the exception of Agriculture Cover Types (2000) and Managed Forest (3000). The anthropogenic non-agricultural GVI site types (Pits, Developed, Rural, and Industrial) were also included in the LUI because some of the GVI features were not present in the ABMI HF data and vice versa. GVI features are defined by photo-interpretation in terms of percent of GVI polygon occupied by a given site type; this refers to the parcel of land being considered for conversion to native perennials

14) ***Proximity to Low Land Use Intensity(PLLUI):*** Select private lands close to lands with low LUI specified as <2%; this refers to adjacent or nearby parcels of the land being considered for conversion

Other criteria (weighting only)

15) ***Land Suitability Rating System class 2 & 3(LSRS23):*** lands at high risk of re-cultivation- if converted to native perennials (LSRS <= 3)
16) ***Land Suitability Rating System class 4(LSRS4):*** Moderate risk of re-cultivation - if converted to native perennials (LSRS = 4)
17) ***Land Suitability Rating System classes 5, 6 & 7(LSRS567):*** low risk of re-cultivation -if converted to native perennials (LSRS >= 5)

Analytical Hierarchy:

The development of an analytical hierarchy enables the ranking of the most important criteria by all participants and across participants by doing a pairwise comparison of each of the 17 criteria to determine the relative importance of each. This facilitates the development of an overall ranking of the criteria from which any cultivated parcel will be analysed and ranked.
Experts were asked to rank pairwise comparisons of criteria (map layers) using a rank scale from 1 to 9 where:

- One (1) means 'equally important to'.
- Nine (9) means 'extremely more important'.

Experts were then asked to indicate in **bold** the more important criterion in every pair and assign an importance value to each comparison. Experts were asked to work on their own, and to avoiding discussion with their colleagues while conducting the pair wise comparisons.

Each expert recorded their comparisons of the 17 variables in 16 separate tables known as importance tables. Table 1 is an example of how proximity to native prairie block (NPB) offset target criteria was compared with each of the sixteen (16) remaining offset target criteria.

Table 1: Offset target criteria relative importance table example for the Native Prairie Block variable relative to the other offset target criteria.

			Importance
NPB	vs.	PPA	1
NPB	**vs.**	ESA	5
NPB	vs.	C&D1	1
NPB	**vs.**	MC	5
NPB	**vs.**	UWR	5
NPB	**vs.**	PFW	5
NPB	**vs.**	PSW	6
NPB	**vs.**	NPL	2
NPB	**vs.**	NPR	3
NPB	**vs.**	CAP	4
NPB	**vs.**	NIRL	7
NPB	**vs.**	LUI	2
NPB	**vs.**	PLLUI	3
NPB	**vs.**	LSRS23	9
NPB	**vs.**	LSRS4	9
NPB	**vs.**	LSRS567	9

If the criteria, in the first column of the relative importance table (Table1) is ***bold faced*;** its corresponding importance value is entered *along the row* of the pair-wise comparison matrix (Table 2). If the criteria, in the first column of the relative importance table (Table1) is *not bold faced***;** its corresponding importance value is entered *along the column* of the pair-wise comparison matrix (Table 2). A value of one (1) is entered in all cells along the diagonal of the pair wise comparison matrix.

Table 2: An illustration of how data from an importance table is entered into a pair-wised comparison matrix.

	NPB	PPA	ESA	C&D1	MC	UWR	PFW	PSW	NPL	NPR	CAP	NIRL	LUI	PLLUI	LSRS23	LSRS4	LSRS567
NPB	1		5		5	5	5	6	2	3	4	7	2	3	9	9	9
PPA	1	1															
ESA			1														
C&D1	1			1													
MC					1												
UWR						1											
PFW							1										
PSW								1									
NPL									1								
NPR										1							
CAP											1						
NIRL												1					
LUI													1				
PLLUI														1			
LSRS23															1		
LSRS4																1	
LSRS567																	1

Criteria weights: Final weights were generated through a series of matrix algebra operations applied to the initial pair wise comparison matrix and the intermediate matrices which followed. The final weights reflect each expert's notion of which criteria are the most important and least important.

Process:

1. Transpose pairwise comparison matrix to a new location below the original matrix.
2. Make a clean version of the transposed matrix by replacing all values of one in the transpose matrix with zero.
3. Create a new matrix where each cell is equal to one divided by the cell value in the cleaned transpose matrix created in step 2.
4. Copy and "paste special" the values of the new matrix from the previous step.
5. Search and Replace all divide by zero errors (#DIV/0!)with a blank cell.
6. Add the cleaned, new matrix to the original pairwise comparison matrix.
7. Create column totals for the matrix created in step 6.

8. Normalize the column value from the matrix created in step 6 by dividing each column value by its column total and store in a new matrix referred to as the normalized matrix.
9. Create row totals for each row in the normalized matrix.
10. Find the minimum row total from the normalized matrix.
11. Create a list of final weights by dividing each row total in the normalized matrix by the minimum row total. This results in a final weighting for each evaluation criteria (each row) in the normalized matrix.

Delphi Process

The Delphi Process determines the appropriate cut offs (choropleth map classes) for spatial decision support data sets used to determine the conservation offset areas for future program development.

Preliminary discussion with all subject matter experts resulted in a list of 17 spatial decision support data sets. After the decision support layers were determined. Subject matter experts were asked to **anonymously** provide a list of 9 choropleth map class cut off values that segregated each decision support data layer into 9 unique map areas:

- The first level of cut off represented areas within the decision support data layer that were considered **most** suitable by the subject matter expert for conservation offset programming.
- The ninth level cut off represented areas within the decision support data layer that were considered **least** suitable by the subject matter expert for conservation offset programming.

These cut off values were organized and summarized so that for each decision support layer cut off value, statistics were determined. (Median, Average, Standard Deviation, and Coefficient of Variation (Standard Deviation / Average).

Once these statistics were determined, a group consensus decision process was followed at a second meeting of experts. At this second meeting, significant changes in standard deviation were leveraged to identify areas where disagreement on cut off for a particular decision support layer existed.

Further discussion and negotiation ensued until agreement among the experts was reached on these cut off intervals.

Consensus was reach on all nine cut off intervals for a decision support layer. The experts made use of the coefficient of variation to further condense the nine cut off intervals into 3 to 5 condensed cut of intervals. Significant changes in the coefficient of variation between adjacent cut off intervals often suggested the optimum breaks for aggregating cut off intervals into more general map classes for each decision support layer.

Two rounds of negotiation meetings were required to secure group consensus. The meetings were held in Lethbridge, Alberta in October and November 2012. One following each completion of the Delphi and Analytical Hierarch process by the subject matter experts. The second completion of the Delphi and Analytical Hierarchy was required as it was determined during the October meeting that further decision support layers were required and some layers were not relevant.

In summary:

- The offset criteria layers have been established.
- The classification breaks for each layer have been established through the Delphi process, and
- The relative importance (weighting) of each criteria layer has been established through the Analytical Hierarchy analysis.

The following section describes how a final scoring map was constructed with this information.

Index Value Calculations

A significant amount of computer processing goes into preparing the criteria layers for the grid algebra processes that result in the final rating map. The whole process was structured so that the processing could be done in an automated fashion. The automation was carried out with ESRI ArcGIS 10.0 using the Python 2.6 scripting environment. The preparation of the criteria layers listed in the Offsets Target Criteria section of this report followed one of two general approaches and please note that outcomes have been rounded for reporting purposes.

1. Twelve of the seventeen criteria layers derive their criteria ratings according to the location's proximity to or distance away from a particular kind of landscape feature. In this approach:
    a. The criteria layers are converted to a grid of equally spaced cells 50 x 50 meters in resolution covering the pilot area of interest, "Native Prairie Block" for example.
    b. The features of interested are assigned a value of 1 and the features not of interest are assigned a value of zero. This is known as creating a binary mask of the features of interest.
    c. Proximity to a feature of interest is calculated using a Euclidian distance, grid algebra, operator on the features of interest grid. The result is a grid where each pixel in the output grid represents its distance in metres from the nearest feature of interest.

d. The proximity grid is re-classified according to the class breaks outlined in the Offsets Target Criteria section of this report. So to follow on from the class breaks example from "step a." of this approach:
    i. The expert panel settled on 5 classes for this criterion layer using the Delphi Process:
        1. Proximity of between 2.5 miles (4,023 metres) – 500 miles (804,672 metres) to a native prairie block was assigned a suitability class of 1
        2. Proximity of between 1.5 miles (2,414 metres) – 2.5 miles (4,023 metres) to a native prairie block was assigned a suitability class of 2
        3. Proximity of between 1 mile (1,609 metres) – 1.5 miles (2,414 metres) to a native prairie block was assigned a suitability class of 3
        4. Proximity of between 1/4 mile (402 metres) – 1.5 miles (1,609 metres) to a native prairie block was assigned a suitability class of 4
        5. Proximity of between 0 miles (0 metres) – 1/4 mile (402 metres) to a native prairie block was assigned a suitability class of 5.
    ii. This same expert panel also assigned an incremental weight or incremental importance to the proximity to native prairie block criterion layer of 11.1083295 through the analytical hierarchy process.
        1. So a pixel with a suitability class value of 1 would have a final rating of (1 X 11) or 11 In a similar manner,
        2. A pixel with a suitability class value of 2 would be rated at 22.
        3. A pixel with a suitability class value of 3 would be rated at 33
        4. A pixel with a suitability class value of 4 would be rated at 44
        5. A pixel with a suitability class value of 5 would be rated at 55

Twelve of the fourteen ecological criteria factors outlined in the table located in the Offsets Target Criteria section of this report would be handled with the first data preparation approach.

2. The remaining 5 criterion layers (2 ecological criterion-LUI, PLLUI and 3 risk criterion- LSRS23, LSRS4, LSRS567) were prepared using a second approach. These layers were not proximity based layers but each pixel had a specific value. These measures were expressed as measures of a specific level of land use intensity or as a measure of a specific kind of land quality. In these five cases:
    a. The criteria layers were converted to a grid of equally spaced cells 50 meters by 50 meters in resolution covering the pilot area of interest.
    b. The criteria layer grids were re-classified according to the class breaks arrived at by the expert panel through the Delphi process described earlier.
    c. Also, an incremental weight or incremental importance derived through the analytical hierarchy process was assigned for each of the pixels in the five remaining gridded criterion layers.

3. When the gridded layers were prepared, criterion class grid layers were multiplied by their corresponding incremental importance layer. The result was a final rating layer for each conservation offset criterion layer. The spatial multiplication was completed using ESRI's map algebra functionality present in the ESRI Spatial Analyst extension.
4. All seventeen of the final rating layers for each conservation offset criterion were then summed, using ESRI Spatial Analyst's map algebra functionality. The result was a final conservation offset rating layer that expressed the final rating for each pixels as the cumulative rating of all the conservation offset criterion layers.
5. A normalized version produced by dividing the final conservation offset rating layer, produced in step 4, by the maximum conservation offset criterion value contained in the grid produced by step 4.
6. The normalized conservation offset rating grid produced in step 5 provides the final scoring map layer.

A python script was developed in the ESRI environment to process and manage the 40 - 50 grid layers produced by this process.

Sourced Material:

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