Ecological Integrity Assessment (EIA) Level 1 Toolbox

The EIA Level 1 Toolbox provides custom tools designed to increase the efficiency of calculating GIS-based EIA metrics for community polygons. The following guide includes general instructions for setting up and using the toolbox, as well as a background into methods and limitations that will help the user understand and correctly interpret the results from the tool.

Toolbox name: EIA_Level1_Toolbox.pyt
Toolbox access: https://github.com/PNHP/EIA_Landscape_Metrics_PA
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1. Introduction and getting started

As a part of the NatureServe Ecological Integrity Assessment Method, there are several Level 1 rapid assessment metrics that can be calculated using remote sensing techniques. The Level 1 rapid assessment metrics can be manually estimated and/or calculated using GIS and remote sensing layers. The EIA Level 1 Toolbox is intended to provide ArcGIS Pro users with a more efficient and standardized way of calculating the Level 1 EIA metrics. However, when using the EIA Toolbox to replace a more manual process, the calculations are a bit of a “black box” to the front-end user. If using the toolbox, it is critically important for the user to understand the methods by which the calculations are made and to interpret the metrics while considering the limitations of the tools.

All metrics calculated by the EIA Level 1 Toolbox have been derived and/or modified from the NatureServe Ecological Integrity Assessment: Protocols for Rapid Field Assessment of Wetlands. v2 publication. Greater detail about the definitions, background, rationale, and protocols for each of the metrics can be found in the NatureServe handbook (Faber-Langendoen, et al., 2016).

Best practices and limitations:

1. The EIA Level 1 Toolbox uses the National Land Cover Dataset (NLCD) raster for calculation of all metrics. It is a best practice to use the most recent NLCD layer to best represent current conditions.
2. The NLCD provides a good approximation of land cover and land use. However, the relatively coarse scale (30-meter) of the raster, the occasional misclassification of land use, and currency of the NLCD layer can lead to a misrepresentation of on-the-ground land use or condition. It is a best practice to critically examine the output metrics with recent aerial imagery layers. In some cases, it may be more appropriate to manually estimate/calculate the Level 1 EIA values using higher resolution or more current remote sensing layers.
3. The PNHP custom Albers coordinate system is used for all geoprocessing done by the EIA Level 1 Toolbox. The custom Albers coordinate system limits distance and area distortion across Pennsylvania, making it the most suitable statewide coordinate system for EIA calculations for the Pennsylvania Natural Heritage Program. If running the toolbox outside of Pennsylvania, the script will need to be updated with a coordinate system best suited for the area of assessment.

To improve the performance of the tool, the input NLCD layer should be re-projected into custom Albers prior to running the tool. If connected to the Pittsburgh WPC network, the default path for the NLCD layer points to a layer that is already projected into custom Albers.

4. The input layer for which you wish to calculate EIA metrics must be a polygon layer. If you have point or line features for which you wish to calculate EIA metrics, it is recommended that you buffer the features by some nominal amount and use the resulting buffered polygon layer.
5. You must have edit privileges for the input layer for which you wish to calculate EIA metrics. Additionally, you must have privileges to edit the input layer schema (for example, to add a field) OR the input layer must already have the EIA metric fields included (lan1, lan1_score, lan2, lan2_score, buf1, buf1_score, buf2, buf2_score, siz1). If you do not have geodatabase schema editing privileges and your input layer does not have the EIA metric fields included, it is recommended that you export the features to a file geodatabase where you have geodatabase schema editing privileges.

2. Accessing and setting up the EIA Toolbox

1. If you are familiar with GitHub, you can fork or clone the PNHP/EIA_Level1_Tools repository to your local machine. Use the ArcGIS Pro Catalog to open the folder where you forked or cloned the repository. The EIA Level 1 Toolbox will be in the EIA_Level1_Tools folder and ready to use. If you are not familiar with GitHub, use the following steps to set up the toolbox.
2. Open a web browser and navigate to:
3. https://github.com/PNHP/EIA_Level1_Tools/blob/main/EIA_Level1_Toolbox.pyt
4. In the upper-right corner of the code block, click the “Download raw file” button
5. The toolbox will now be in your Downloads folder. If you wish, copy and paste the toolbox to another location on your machine.
6. Open ArcGIS Pro and in your Catalog, right-click the ‘Toolboxes’ folder and select ‘Add Toolbox’.
7. Navigate to the location where you saved the toolbox, click the toolbox, and click “Okay”. Optionally, you can right-click the toolbox and add it to your Favorites.
8. Your toolbox is now ready to use just like any ArcGIS Pro toolbox!

3. Calculate Level 1 EIA Metrics

The front-end of the Calculate Level 1 EIA Metrics Tool is relatively simple. However, it is important to understand the methods by which the metrics are being calculated.

3.1 Running the Tool

The data and parameters that are needed to run the tool include:

1. Selected Communities - a polygon feature layer that includes a selection on the features for which you wish to calculate the metrics.
    a. The feature layer must include the Level 1 EIA fields OR the database schema of the feature layer must be editable by the user.
    b. Ensure that ONLY the features for which you wish to calculate metrics are selected. If a selected feature already has metrics, they will be overwritten.
2. National Land Cover Dataset (NLCD) raster layer.

   a. Performance will be improved if the NLCD raster layer is already projected into the custom Albers spatial coordinate system.
3. Scratch Geodatabase - an existing geodatabase where the intermediate geoprocessing files will be written.
4. Option to save subzone metrics to a .csv file. The .csv file will be written to the folder where the scratch geodatabase exists.

3.2 Output Metrics

3.2.1 LAN1 Contiguous Natural Land Cover

The LAN1 metric is a measure of connectivity assessed using the percent of natural habitat directly connected to the community polygon within a 500-meter buffer. If the user chooses the option to calculate subzone metrics to a .csv file, the measure of connectivity within buffer subzones will be calculated as well. The buffer subzones include 0-100 meters and 100-500 meters. The output .csv file will be named "LAN1_values" and written to the folder where the scratch geodatabase exists.

To calculate the LAN1 metric, a multi-part buffer, from 0-100 meters and 100-500 meters, is applied to the assessment area (Figure 1b). The NLCD raster is clipped by the buffers, vectorized, and the natural land cover classes are isolated in a single part polygon layer (Figure 1c). To ensure contiguous natural land cover is used in the calculation, only natural land cover polygons that intersect the assessment area are selected and exported (Figure 1d) to calculate the LAN1 metric. The area of the contiguous natural land cover is then divided by the total area of the full 500-meter buffer and multiplied by 100 to get the final LAN1 metric.

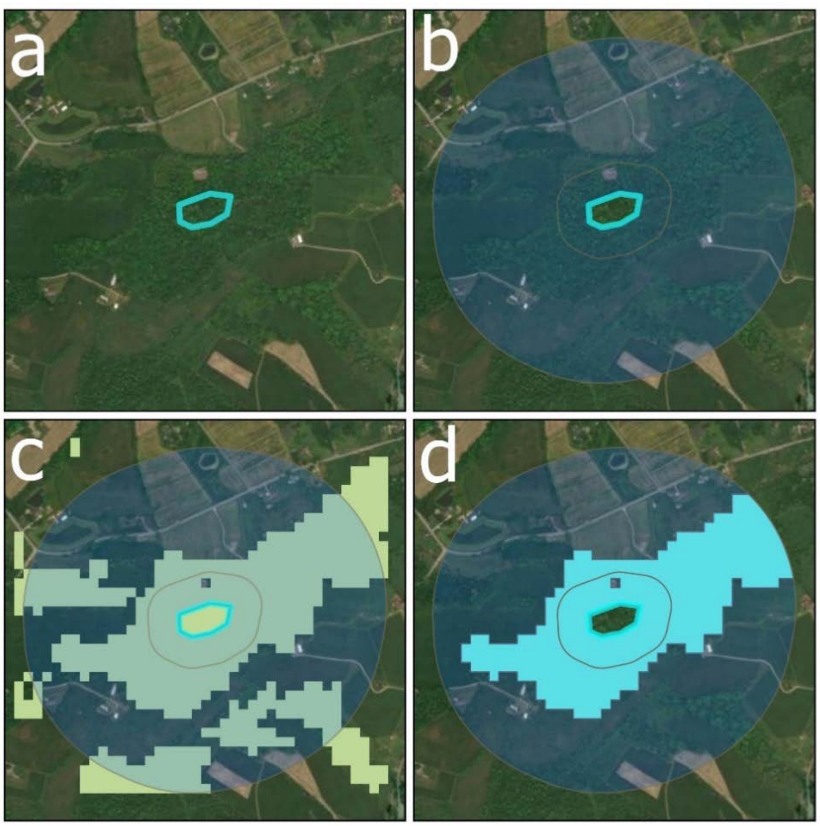


Figure 1. Example of GIS methods used to calculate the LAN1 metric. (a) the selected assessment area that is used as an input to the tool. (b) a multi-part buffer is applied to the selected assessment area. (c) the NLCD raster is clipped to the buffer area,

vectorized, and natural land cover classes are isolated in single-part polygons. (d) natural land cover polygons are selected if they intersect the assessment area and exported to a new layer that is used to calculate the percent of contiguous natural land cover within the 500-meter buffer.

The NLCD land cover classes were classified as natural or non-natural based on typical expected condition (Table 1). It is important for the user to review aerial imagery for cases where the cover type assumptions in Table 1 may not be appropriate. For example, it may be more suitable to classify a heavily impacted water impoundment as non-natural even though it may be classified as open water in the NLCD. In these cases, the LAN1 metric calculated by the tool may not be appropriate and may need to be manually estimated or calculated based on more detailed remote sensing data.

Table 1. Land cover type classifications by NLCD land cover class.

Land Cover Class	Cover Type
Unclassified	Natural
Open Water	Natural
Perennial Snow/Ice	Natural
Developed, Open Space	Non Natural
Developed, Low Intensity	Non Natural
Developed, Medium Intensity	Non Natural
Developed, High Intensity	Non Natural
Barren Land	Non Natural
Deciduous Forest	Natural
Evergreen Forest	Natural
Mixed Forest	Natural
Shrub/Scrub	Natural
Herbaceuous	Natural
Hay/Pasture	Non Natural
Cultivated Crops	Non Natural
Woody Wetlands	Natural
Emergent Herbaceuous Wetlands	Natural

3.2.2 LAN1 Score

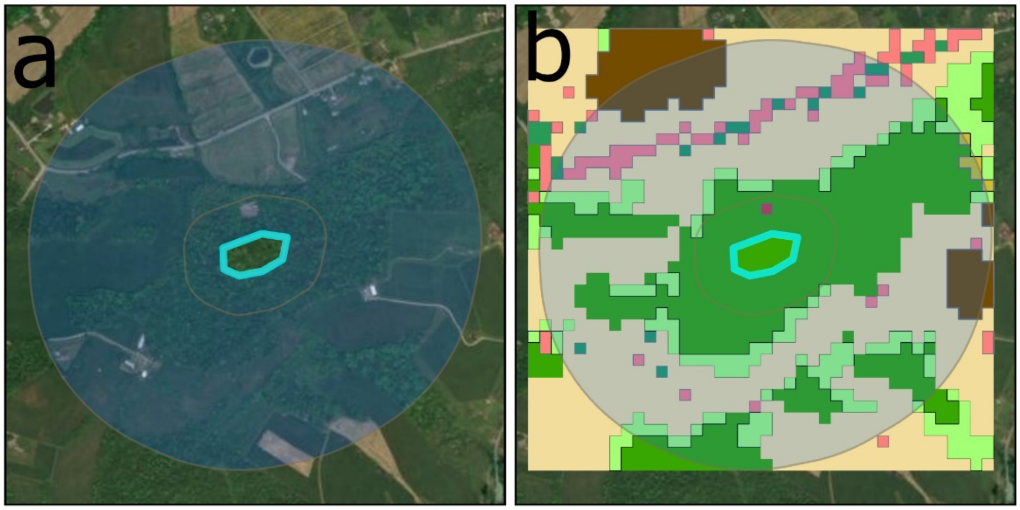
The LAN1 Score is determined based on the LAN1 metric, the percent of contiguous natural land cover (Table 2).

Table 2. Contiguous Natural Cover Metric Score

Metric Rating	Contiguous Natural Land Cover
A - EXCELLENT	90-100%
B - GOOD	60-90%
C - FAIR	20-60%
D - POOR	<20%

3.2.3 LAN2 Land Use Index

The LAN2 metric is a measure of the intensity of human activity within the 500-meter buffer surrounding the selected assessment area. The LAN2 metric is calculated by multiplying the percent of land use cover type by a land use coefficient within the 0-100-meter subzone and the 100-500-meter subzone (Figure 2c). These scores are summed within subzones and weighted (0.6 for the inner subzone and 0.4 for the outer subzone) before being added together for the final LAN2 metric (Figure 2d). If the user chooses the option to calculate subzone metrics to a .csv file, intermediate calculations within subzones will be written to an output .csv file named “LAN2_values” and located in the folder where the scratch geodatabase exists.



c

Subzone	Land Cover Class	Subzone %	LAN2 Coefficient	% x Coefficient	
Inner	Developed, Medium Intensity	1.179365	0	0	
Inner	Deciduous Forest	98.275784	10 Σ	9.827578	= 9.88
Inner	Mixed Forest	0.54485	10	0.054485	
Outer	Developed, Open Space	4.183574	1	0.041836	
Outer	Developed, Low Intensity	1.390003	0	0	
Outer	Deciduous Forest	27.068033	10	2.706803	
Outer	Evergreen Forest	0.300334	10 Σ	0.030033	= 6.54
Outer	Mixed Forest	11.396944	10	1.139694	
Outer	Hay/Pasture	50.409493	5	2.520475	
Outer	Cultivated Crops	5.25162	2	0.105032	

d $(9.88 \times 0.6) + (6.54 \times 0.4) = \boxed{8.54}$

Figure 2. Example of GIS methods to calculate LAN2. (a) a multi-part buffer is applied to the selected assessment area. (b) the NLCD is clipped to the buffer area and vectorized. (c) tabulate intersect is run on the multi-part buffer and NLCD vector layer, resulting in a table of the percent of intersecting land cover classes within each buffer subzone. The percent intersect is multiplied by the LAN2 coefficient and these values are summed within subzones. (d) the summed subzone values are weighted and added together to get the final LAN2 metric.

The LAN2 land use index coefficients were derived from Faber-Langendoen, et al., 2016 to best reflect intensity of human activity within the different land use types represented in the NLCD layer (Table 3). It is important for the user to review aerial imagery for cases where the land use index coefficients in Table 3 may not be appropriate. For example, it may be more suitable to use a lower coefficient for a heavily impacted water impoundment even though we are considering open water a natural cover by default. In these cases, the LAN2 metric calculated by the tool may not be appropriate and may need to be manually estimated or calculated based on more detailed remote sensing data and modified coefficients.

Table 3. LAN2 land use index coefficients for land use types represented in the NLCD.

Land Cover Class	LAN2 Coefficient
Unclassified	10
Open Water	10
Perennial Snow/Ice	10
Developed, Open Space	1
Developed, Low Intensity	0
Developed, Medium Intensity	0
Developed, High Intensity	0
Barren Land	6
Deciduous Forest	10
Evergreen Forest	10
Mixed Forest	10
Shrub/Scrub	7
Herbaceuous	10
Hay/Pasture	5
Cultivated Crops	2
Woody Wetlands	10
Emergent Herbaceuous Wetlands	10

3.2.4 LAN2 Score

The LAN2 Score is determined based on the LAN2 metric, the land use index (Table 2).

Table 4. Land Use Index Metric Score.

Metric Rating	LAN2 Land Use Index Score
A - EXCELLENT	9.5-10
B - GOOD	8.0-9.4
C - FAIR	4.0-7.9
D - POOR	<4.0

3.2.5 BUF1 Perimeter with Natural Buffer

The BUF1 metric is a measure of the percent of the assessment area perimeter with a vegetated, natural buffer. To calculate the BUF1 metric, the selected assessment area polygon is converted to a line feature and intersected with the vectorized natural land cover layer created during the LAN1 calculations (Figure 3). The length of the perimeter intersecting natural land cover is then divided by the total perimeter length and multiplied by 100 to get the percent of perimeter with a natural buffer. It is important for the user to review aerial imagery to ensure the NLCD appropriately reflects the land use conditions. Because the NLCD is relatively coarse at a 30-meter pixel size, there are some instances where it may be more appropriate to use higher resolution data to determine the percent of natural cover intersecting the assessment area perimeter.

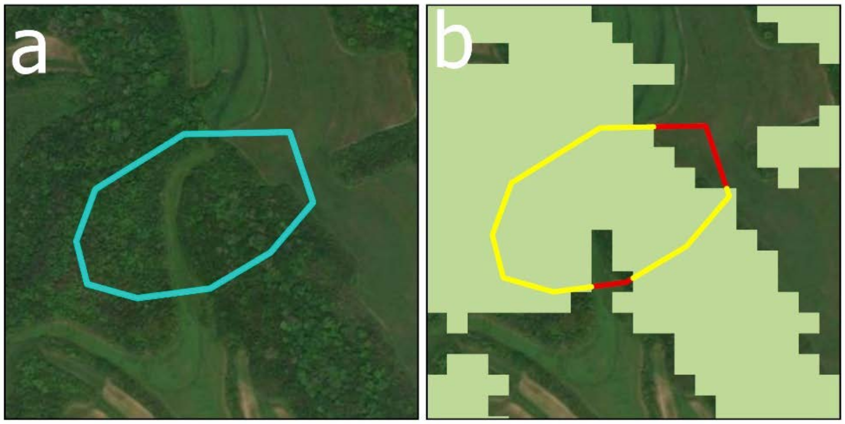


Figure 3. Example of GIS methods to calculate BUF1. (a) the selected assessment area polygon is converted to a line feature. (b) the line feature is intersected with the natural land cover from the vectorized NLCD (yellow portions of the perimeter are considered to have a natural buffer; red portions of the perimeter have non-natural buffer). The percent of perimeter with a natural buffer becomes the final BUF1 value.

3.2.6 BUF1 Score

The BUF1 Score is determined based on the BUF1 metric, the percent of perimeter with natural buffer (Table 5).

Table 5. Perimeter with Natural Buffer Metric Score.

Metric Rating	BUF1 Perimeter with Natural Buffer (%)
A - EXCELLENT	100%
B - GOOD	75-99%
C - FAIR	25-74%
D - POOR	<25%

3.2.7 BUF2 Width of Natural Buffer

The BUF2 metric is the measure of the average width of the natural buffer surrounding the assessment area up to a maximum distance of 100 meters. To calculate the BUF2 metric, 30 100-meter long "spokes" are created at equal intervals around the selected assessment area (Figure 4b). The spokes are then intersected with the natural land cover vector layer created for the LAN1 metric. Of the "spokes" that remain, those that are not contiguous with the selected assessment area are removed (Figure 4c). Finally, the lengths of all remaining "spokes" are summed and divided by 30 to get the final BUF2 metric, the average width of the natural buffer (Figure 4d). For greater detail about the specific geoprocessing methods used to create the "spokes", refer to the commented Python code supplied on GitHub.

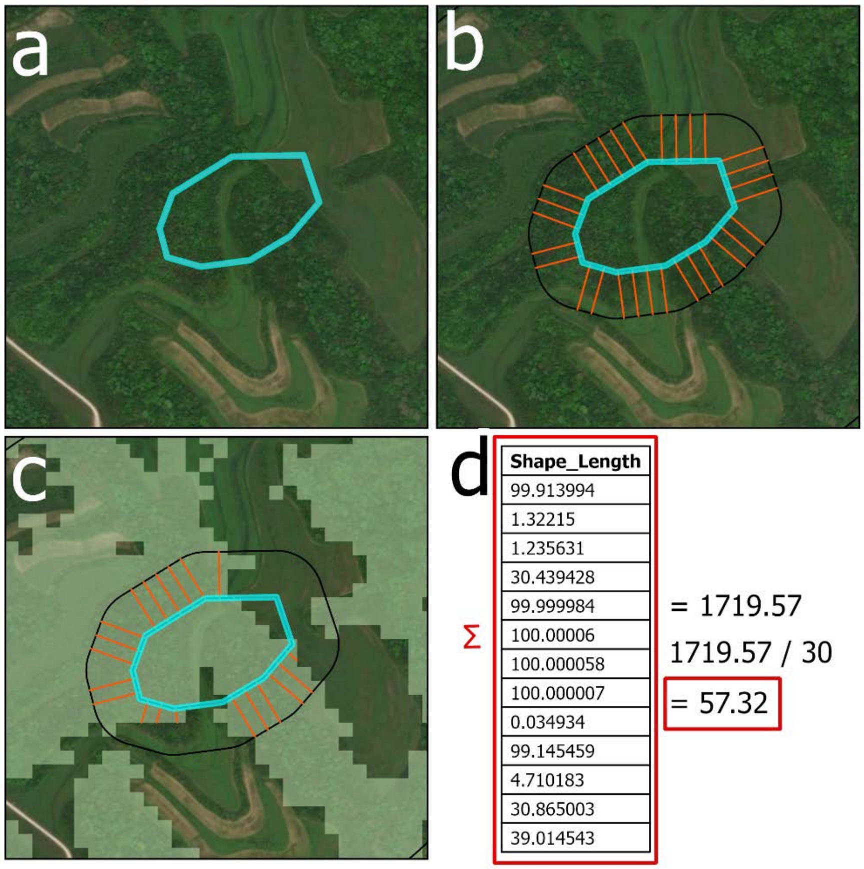


Figure 4. Example of GIS methods to calculate BUF2. (a) the selected assessment area polygon is converted to a line feature. (b) 30 100-meter-long "spokes" are created at equal intervals along the assessment area line feature. (c) the "spokes" are intersected with the natural land cover vector. If a "spoke" is not contiguous with the assessment area, it will be excluded. (d) the lengths of all remaining "spokes" are summed and divided by 30 to get the final BUF2 metric, the average width of natural buffer.

BUF2 CONSIDERATIONS: The methods used to calculate the BUF2 metric are derived from the Faber-Langendoen, et al., 2016 publication, however, they are heavily modified and include limitations that the user should fully understand. Be aware of the following considerations and limitations:

1. There is an underlying assumption that the input assessment area is more-or-less normal in shape; circular or oval. If your assessment area has a more complex shape, see the guidance in the Faber-Langendoen, et al., 2016 publication to determine whether a manual approach to calculating the BUF2 metric is more appropriate.
2. The Faber-Langendoen, et al., 2016 publication instructs the user to draw 8 "spokes" around the assessment area to measure the average natural buffer width. Because we have automated this process and a user is not determining where to place the spokes, we found that including a higher number of "spokes" more accurately represented the buffer width surrounding the assessment area. We chose to create 30 "spokes" as our default because it provided a high enough sample size to accurately represent the buffer width surrounding one of our typically sized assessment areas, while not reducing performance of the tool. It may be appropriate to

reconsider the number of "spokes" used if calculating BUF2 for an atypically large assessment area.

3. The Faber-Langendoen, et al., 2016 publication recommends adjusting the rating of the upslope buffer width based on the degree of slope (Table 6). This tool **DOES NOT** consider slope, and because the BUF2 metric rating categories in Table 7 assume that the metrics have been adjusted for slope, the BUF2 Score may be under ranked by the tool.

Table 6. Adjusting rating of upslope buffer.

Slope Gradient	Additional Buffer Width Multiplier
5–14%	1.3
15–40%	1.4
>40%	1.5

3.2.8 BUF2 Score

The BUF2 Score is determined based on the BUF2 metric, the average width of natural buffer (Table 7). Note that the metric ratings in Table 7 are adjusted for slope, however, the tool **DOES NOT** adjust the BUF2 metric for slope. It may be appropriate for the user to account for slope according to Faber-Langendoen, et al., 2016 and manually update the BUF2 metric and resulting score according to Table 7.

Table 7. Width of natural buffer metric rating.

Metric Ratings	Average Buffer Width (m)
EXCELLENT (A)	≥100 m, adjusted for slope.
GOOD (B)	75–99 m, after adjusting for slope.
FAIR (C)	25–74 m, after adjusting for slope.
POOR (D)	<25 m, after adjusting for slope.