**Online Resource 1:** This section provides a brief description of the metrics derived in this study. Metrics are grouped according to the characteristics they measure, although there is some overlap between categories. Many of these metrics are based on 2D analogue landscape metrics in FRAGSTATS (McGarigal et al. 2012). We index individual pixels with *p,* individual objects with *i*, and classes of objects with *j*.We first describe the three fundamental metrics that provide a basis for the derivation of the other metrics.

**Fundamental Metrics**

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| Number of Objects  (NO) | Number of discrete objects, computed as the number of objects of the corresponding object type (class) *j*, in the landscape |
| Surface Area  (SA) | The surface area (m2) of a 3D object. *SA* ranges [0, ∞] and is bounded by the total volume of the study area, where *hp* and *wp* are the height and width of a pixel *p* that intersect the boundary of the 2D spatial footprint, *F,* of object *i* (to calculate the area of object sides), and *ap* is the area of pixels within the 2D spatial footprint object *i* (to approximate the top of the object). |
| Volume  (VOL) | The volume (m3) of a 3D object. *VOL* ranges [0, ∞] and is bounded by the total volume of the study area. For the calculation of *VOL, ap* and *hp* are the area and height of pixels *p*, within the 2D spatial footprint, *F,* of object *i.* |

**Object-based Metrics**

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| Object Density  (OD) | The density of objects in a study area is the number of objects of a particular class divided by the study area, multiplied by 1,000,000 to convert to number of objects per square kilometer. |
| Object Richness  (OR) | Object richness is the number of different object classes within the landscape, where equals the number of different object types (classes) within the landscape  = c |
| Object Richness Density (ORD) | The object richness density of a landscape is the number of different object classes divided by total landscape area (*A*), multiplied by 1,000,000 to convert to square kilometers: |

**Surface Area-based Metrics**

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| Largest Object Surface Area Index  (LOSAI) | The surface area of largest object in a landscape is computed as the percent of total object surface area in that landscape: |
| Percentage of Landscape Object Surface Areas  (PLOSA) | The percent of total object surface area for all object of a single type (class) *j*, is computed as the sum of that class’s surface area divided by the total surface area of all objects in all classes *c*: |
| Shannon’s Diversity of Surface Area Index (SHDSAI) | Shannon’s diversity equals minus the sum of the surface area-based proportional abundance (*PLOSA*) of each class *j* multiplied by the natural log of that proportion: |
| Simpson’s Diversity of Surface Area Index (SIDSAI) | Simpson’s diversity equals one minus the sum, across all object classes *c*, of the surface area-based proportional abundance (*PLOSA*)of each object class *j* squared |

**Volume-based Metrics**

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| Largest Object Volume Index  (LOVI) | The object with the largest volume relative to the volume of all objects in a class *j* is computed as the ratio of the volume of the largest object, max(VOLij) to the sum of the volume of all objects in a class |
| Percentage of Landscape Object Volume  (PLOV) | The percent of total object volume for all object of a single type (class) *j*, is computed as the sum of that class’s volume divided by total volume of all objects in all classes *c*: |
| Percent of Landscape Volume  (VPLAND) | Percent of landscape volume standardizes the volume of a class *j* using the total volume of the study area, which is horizontally bounded by the perimeter of the study area, and vertically bounded by the height of the tallest object within the study area boundary. Total landscape volume is computed using landscape area, *A,* and the height of the tallest pixel max *(hp)* in landscape*.* This metric provides a measure of how densely packed the 3D space of a study area is with objects of a particular class, or, if analyzed at the landscape level, all 3D objects. |
| Shannon’s Diversity of Volume Index  (SHDVI) | Shannon’s diversity equals minus the sum of the percentage of landscape object volume (*PLOV*) classes *j* multiplied by the natural log of that percentage: |
| Simpson’s Diversity of Volume Index  (SIDVI) | Simpson’s diversity equals one minus the sum, across all object classes *c*, of the volume-based proportional abundance (*PLOV*)of each object class *j* squared |

**Shape Metrics**

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| Surface Area to Volume Ratio  (SAVR) | The ratio of 3D object surface area (m2) to volume (m3) is an unstandardized measure of shape that varies with object size. *SAVR* of an object *i* is calculated as, |
| Three Dimensional Shape (3DSHAPE) | *3DSHAPE* equals the surface area of an object *i* divided by the minimum surface area of a maximally compact cubic object of a volume equal to the object *i*. This metric provides a standardized measure of 3D object complexity by referencing any object to a cube. We use a reference cube, but other reference objects are possible (e.g., a reference sphere for tree canopy shape). The *3DSHAPE* of an object *i* is computed as, |

**Distribution Statistics**

Distributional statistics summarize the attributes of the fundamental metrics, volume (VOL) and surface area (SA) of sets of 3D objects and can be computed at the class and landscape levels. When objects are differentiated into classes based on some attribute (e.g., height, type), class-level metrics measure the distribution of object attributes within each class. Landscape-level metrics measure the aggregate properties of object attributes when all classes are analyzed together.

Descriptive statistics of mean (\_*MN*), median (\_MD), range (\_*RA*), standard deviation (\_*SD*), and coefficient of variation (\_*CV*) are all calculated following standard statistical procedures with individual 3D objects acting as observations.

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| Mean  (\_MN) | Mean is the sum of the metric value, *x* (e.g., VOL) across all objects of class *j*, divided by the number of objects of the same type, |
| Median  (\_MD) | Median equals the metric value, *x* of the object metric at the midpoint of the rank order distribution of metric values of objects of class *j* |
| Range  (\_RA) | The range is the largest metric value, *x* observed minus the smallest metric value observed for objects of class *j*, |
| Standard Deviation  (\_SD) | Standard deviation is equal to the square root of the sum of the squared deviations of each object metric value, *x* from the mean metric value of the corresponding object class, divided by the number of objects of the same class, |
| Coefficient of Variation  (\_CV) | Coefficient of variation is the standard deviation of an object class, *j*, divided by the mean of the object class. That value is multiplied by 100 to convert it to a percentage, |

In addition to the standard distributional statistics, we present volume-weighted mean (*\_VM*) and surface area-weighted mean (*\_SAM*) metrics that weight the calculation of the mean by the proportional volume and surface area of each patch.

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| Surface area-weighted mean  (\_SAM) | Surface area weighted mean weights each object *i* by its surface area relative to the surface area of all objects in that class*,* |
| Volume-weighted mean (\_VM) | Volume weighted mean weights each object *i* by its volume relative to the volume of all objects in that class*,* |