Detection and identification of archaeological features using aerial LIDAR data in a forested environment (Châtillon-sur-Seine, Côte-d’Or, France).

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The study area is located in the northern part of the Côte d’Or (Burgundy, France) in the state forest of Chatillon-sur-Seine (a). The place is covered by sets of protohistoric to medieval dry-stone structures were GPS prospection investigations were performed during ten years (Vix Program). To complete this prospection, LiDAR data were acquired by PNF (Parcs Nationaux de France) in 2012, on a 400 km² area.

The objective of this work is to identify feature types defined for GPS prospection from LiDAR data indices. To evaluate the recognition of feature type with LiDAR data, we used two indices calculated on the LiDAR DEM (50 cm resolution). The local slope map highlights morphological variations of each feature, leading to define feature type. As some features present the same appearance on slope map, the topographic positive openness was calculated to determine the negative or positive elevation of features. For openness index, we used 8 directions on a 20 pixels radius distance (10 m diameter).

**GPS typology VS LiDAR data**

<table>
<thead>
<tr>
<th>Feature Type</th>
<th>Definition</th>
<th>2D representation</th>
<th>Local slope</th>
<th>Positive openness</th>
<th>Key factors of recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Murée (b)</td>
<td>Dry-stone wall; plot limits</td>
<td><img src="image1" alt="Image" /></td>
<td>low slope in centerline = top of the wall; medium slope with the same footprint around centerline = two sides of the wall</td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td>Murée sur épaulement</td>
<td>Dry-stone wall or anthropogenic embankment; plot limits</td>
<td><img src="image4" alt="Image" /></td>
<td>low slope in centerline = top of the wall; medium slope with wide footprint = embankment and wall side; medium slope with small footprint = wall side</td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
<tr>
<td>Épaulement</td>
<td>Nature or anthropogenic embankment; plot limits</td>
<td><img src="image7" alt="Image" /></td>
<td>medium slope with wide footprint = embankment</td>
<td><img src="image8" alt="Image" /></td>
<td><img src="image9" alt="Image" /></td>
</tr>
<tr>
<td>Fossé</td>
<td>Ditch; plot limits</td>
<td><img src="image10" alt="Image" /></td>
<td>low slope in centerline = ditch bottom; medium slope with the same footprint around centerline = two sides of the ditch</td>
<td><img src="image11" alt="Image" /></td>
<td><img src="image12" alt="Image" /></td>
</tr>
<tr>
<td>Chemin/Voie (c)</td>
<td>Path/Roman road; communication road</td>
<td><img src="image13" alt="Image" /></td>
<td><img src="image14" alt="Image" /></td>
<td><img src="image15" alt="Image" /></td>
<td><img src="image16" alt="Image" /></td>
</tr>
<tr>
<td>Tertre (d)</td>
<td>Dry-stone mound; sree or plot limit (aligned) or tumulus</td>
<td><img src="image17" alt="Image" /></td>
<td>Circular to ovoid forms (rarely quadrangular); low slope in center = top of the mound, medium slope surrounding center = moundsides</td>
<td><img src="image18" alt="Image" /></td>
<td><img src="image19" alt="Image" /></td>
</tr>
<tr>
<td>Excavation (minière ou lavière)</td>
<td>Excavation; mining or quarry</td>
<td><img src="image20" alt="Image" /></td>
<td>Circular form; low slope in center = bottom of the excavation, medium slope surrounding center = excavation sides</td>
<td><img src="image21" alt="Image" /></td>
<td><img src="image22" alt="Image" /></td>
</tr>
<tr>
<td>Place à feux</td>
<td>Charcoal burning, charcoal place production</td>
<td><img src="image23" alt="Image" /></td>
<td>Circular form; low slope in center area = fire place, two medium slope surrounding center area with crescent shaped = one is dug border and the other is backfilled border</td>
<td><img src="image24" alt="Image" /></td>
<td><img src="image25" alt="Image" /></td>
</tr>
<tr>
<td>Tertre surfacique</td>
<td>Surficial dry-stone mound, more than 10 m diameter; probably tumulus</td>
<td><img src="image26" alt="Image" /></td>
<td>Circular to ovoid forms higher than 10 m diameter; low to medium slope in center = top of the mound, medium to high slope surrounding center = mound sides</td>
<td><img src="image27" alt="Image" /></td>
<td><img src="image28" alt="Image" /></td>
</tr>
<tr>
<td>Four à chaux</td>
<td>Lime kiln; lime place production</td>
<td><img src="image29" alt="Image" /></td>
<td>Circular form higher than 10 m diameter; high slope in the center = excavation; low slope around center = top of the mound; medium slope outside = side of the mound; access area to center feature</td>
<td><img src="image30" alt="Image" /></td>
<td><img src="image31" alt="Image" /></td>
</tr>
<tr>
<td>Cairrière</td>
<td>Quarry, place of stone extraction</td>
<td><img src="image32" alt="Image" /></td>
<td>No particular form; high slope with small footprint = quarry face, low slope = extracted area</td>
<td><img src="image33" alt="Image" /></td>
<td><img src="image34" alt="Image" /></td>
</tr>
</tbody>
</table>

**Application and validation**

This method was applied on a 2.5 km² area, where:
- 106 line, 192 point and 12 surface features were recorded by GPS
- 164 line, 398 point and surface features were recorded by LiDAR

Feature types recognized by LiDAR were compared to GPS records.

- **70 % of linear features observed with LiDAR were great classified**
  - 1 % forgotten
  - 5 % misclassified (Murée <> Épaulement)
  - 10 % misclassified (Murée sur épaulement)
  - 14 % misclassified (Murée <> Murée sur épaulement)
- **81 % of point features from LiDAR were great classified**
  - 5 % forgotten
  - 5 % not visible
  - 3 % double GPS acquisitions on the field
  - 6 % misclassified (elargished mound were classified as small embankment)
- **84 % of surface features from LiDAR were great classified**
  - 8 % classified as multi features
  - 8 % misclassified with GPS (lower than 10 m diameter)

To evaluate GPS and LiDAR classification availability, 2D cross-sections were performed on the LiDAR DEM for all misclassification areas.

The results show that LiDAR data recognition is conform to 2D topographic profile.

The misclassification of features observed on GPS data may be due to:
- A bad estimation of low topographical variations on the field
- A continuous record on the field, which do not take into account all morphological changes (observable on LiDAR) on a linear structure

**Discussion**

This work shows that local variations of slope values combined with topographic positive openness facilitate the detection of new structures and their assignments to one of the typology defined by the GPS prospection.

The high altimetric resolution of LiDAR data allows to observed low topographical changes, with decimetric variations. However, the location of these features is not easy to be assessed, and the determination of feature types is almost impossible. Therefore, a return to the field is needed to validate the assumptions from LiDAR data.