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Exploring the Usefulness of Land Parcel Data for Evaluating Multi-Temporal Built-up Land Layers

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The increasing amount of free and open remote sensing data suggests that a number of multi-temporal land use and built-up land datasets derived from remotely sensed imagery will be made available soon. However, little research has been done regarding the approaches to evaluate spatiotemporal uncertainty of such products. Employing publicly available cadastral data with information on construction date may be useful for this purpose but requires developing a proper validation protocol. In this work we present preliminary results from a feasibility study that examines the potential use of land parcel data as reference data for spatiotemporal evaluation of such built-up land data, exemplified by the novel Global Human Settlement Layer (GHSL). The results indicate that alternative strategies shall be considered, as the use of parcel data tends to bias the evaluation results due to inherent mismatches between the two data sources, especially in rural areas.

I INTRODUCTION

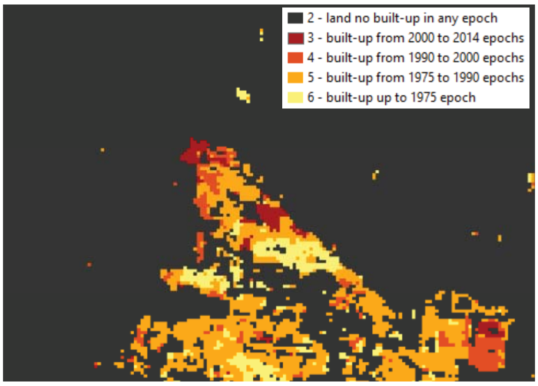
The Global Human Settlement Layer (GHSL) is a methodology developed to identify and map built-up areas from Landsat satellite imagery (Pesaresi et al. 2013) and create a new global information baseline describing the spatial evolution of the human settlements in the past 40 years (Pesaresi et al. 2016). This global dataset is available at high spatial resolution (38m) and for various periods of time (around 1975, 1990, 2000, and 2014). GHSL data may provide new opportunities for population projections (Freire et al. 2016), disaster management and risk assessment (Freire et al. 2015), as well as for analysing and modelling urban dynamics and land use change.

Before making such novel data products available to the research community, an extensive quality assessment is needed to demonstrate their usability. However, such assessments are difficult and rarely done due to the lack of reliable reference data, particularly for earlier time periods and in less developed regions. We carried out a first experiment to evaluate multi-temporal spatial data on built-up land such as GHSL or developed land cover classes in a typical land cover database using publicly available tax parcel (cadastral) data. How meaningful reference layers based on parcel data can be, represents an open question. This study is meant to shed light on the feasibility of such evaluations in order to establish a thorough protocol for validation studies in the near future.

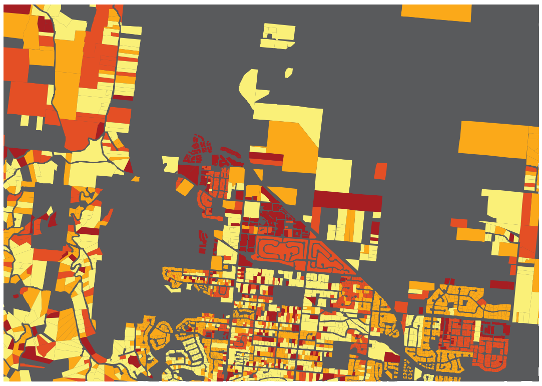
II DATA AND METHOD

Open data policy makes cadastral and tax assessment data publicly available – often as GIS-compatible format – for many regions in the U.S. Often these parcel data contain rich attribute information related to the type of land use, characteristics of the structure and the year when a structure in a parcel has been established (built year). To create spatiotemporal reference layers, the built year attribute is used to reconstruct snapshots of parcel-derived built-up areas that correspond to the GHSL time spans of built-up land (before 1975=class 6, 1975-1990=class 5, 1990-2000=class 4, 2000-2014=class 3) and its non-built-up land (class 2).

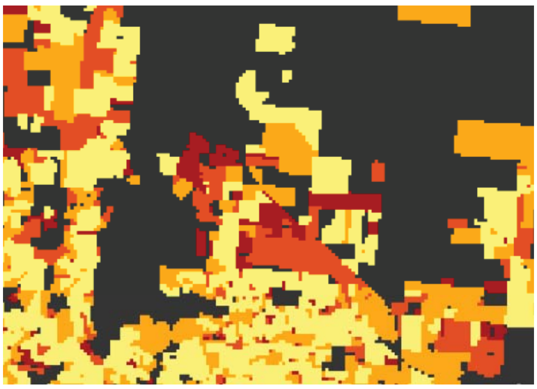
For each time span, GHSL built-up land is compared with parcel-derived built-up areas. This has been implemented in a raster-based approach where parcel polygons are rasterized to match the spatial resolution of GHSL (approx. 38m) using the time-span class as raster value (values 2-6). In order to comply with the GHSL-based built-up land definition, a pixel is classified as built-up when it overlaps with a built-up entity (Pesaresi et al. 2016). In this first experiment the parcel area is used as a proxy for built-up land despite well-known limitations (see below). This reference raster dataset is overlain with the original GHSL data and pixel-based confusion matrices are built to derive various accuracy metrics (Fielding and Bell 1997) for each time period. These metrics can be derived to quantify the classification accuracy of GHSL for each time span (cumulatively e.g., class 4 labels built-up land before 2000 including classes 5 and 6) and provide rich material for assessing its quality across space and time. Figure 1 shows GHSL built-up labels (a) and created reference data (b and c) for a subset of Boulder County, CO.



(a) GHSL raster data for Boulder, Colorado



(b) Parcels with built year (polygon objects)



(c) Parcels rasterized to GHSL resolution

Figure 1: GHSL built-up labels and corresponding reference data for North Boulder, Colorado.

Parcel data including built year information is publicly available for different administrative regions in the U.S. (states, counties, and cities) but not a standard product. In order to test parcel data for evaluation of GHSL in different settings with regards to development intensity, we included two rather rural (Figure 2) and two urban counties (Figure 3).

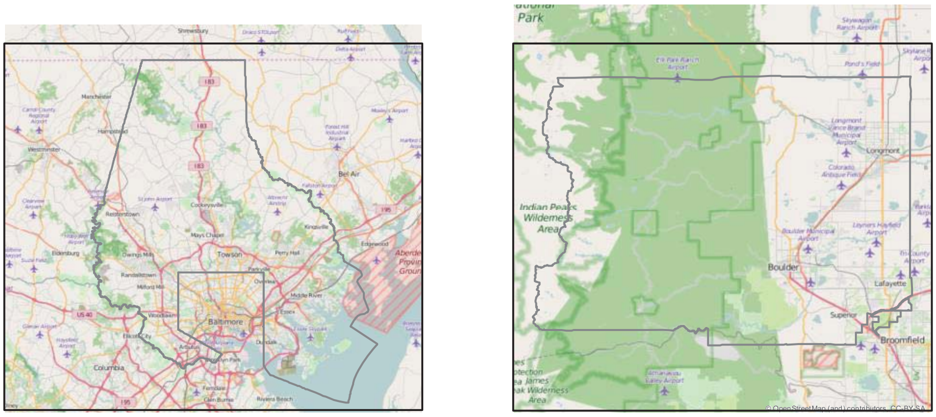


Figure 2: Rural study areas: Baltimore County (excludes the city of Baltimore), Maryland (left), and Boulder County, Colorado (right). Basemap: Open Street Map.

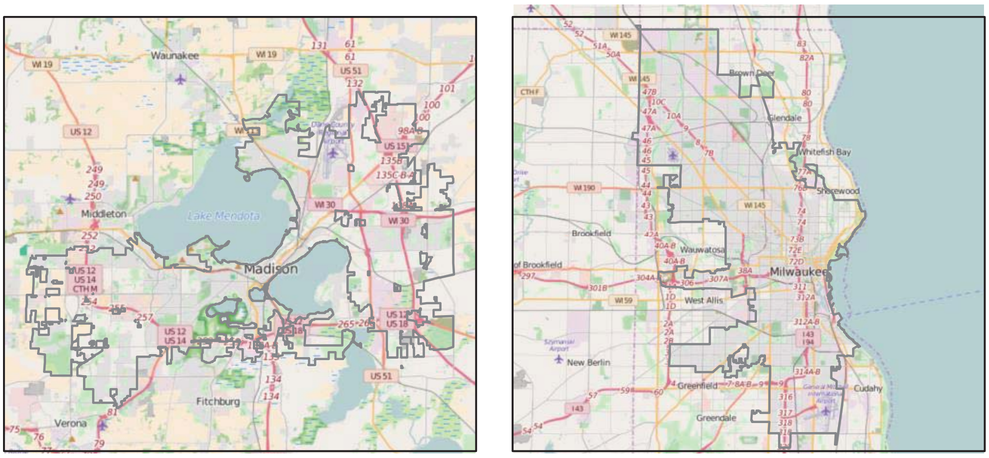


Figure 3: Urban study areas: City of Madison, Wisconsin (left), and Milwaukee County, Wisconsin (right). Basemap: Open Street Map.

III RESULTS

The results are based on the comparison of GHSL with the parcel-derived reference surface and intended to illustrate the feasibility of using parcel data to evaluate multi-temporal built-up land data. Confusion matrices are created for all time spans in both settings (Figures 4 and 5) and overall agreement metrics are shown in Table 1 for each study area. There are noticeable differences in agreement between rural and urban settings (e.g., Producer's Accuracy or Kappa).

	Average Producer's Accuracy	Average User's Accuracy	Kappa	Normalized Mutual Information	Overall Agreement	Average Omission Error	Average Commission Error
Madison (urb.)	0.497	0.428	0.284	0.153	0.568	0.503	0.572
Milwaukee (urb.)	0.369	0.304	0.220	0.095	0.538	0.631	0.696
Boulder (rur.)	0.275	0.636	0.155	0.062	0.673	0.725	0.364
Baltimore (rur.)	0.284	0.387	0.140	0.035	0.462	0.716	0.613

Table 1: Overall accuracy measures for the four study areas.

Confusion matrices for urban areas (Figure 4) show that while there is some variation among counties, in general the agreement for class 2 (non-built-up) and class 6 (built before 1975) is high. Yet, large portions of non-built-up areas (class 2) in parcel data have been classified as built-up before 1975 (class 6) in GHSL.

For rural areas very high agreement can be seen in non-built-up land. However, higher portions of built-up pixels in the parcel surface in all epochs (particularly class 6) have been classified as non-built-up pixels in GHSL (Figure 5) decreasing Producer's Accuracy. A possible explanation could be that portions of large rural residential parcels, which are mostly of agricultural use, are falsely assumed (and thus overestimate) built-up land in the reference data. These portions are often correctly classified as not built-up land (class 2) in GHSL resulting in this kind of disagreement.

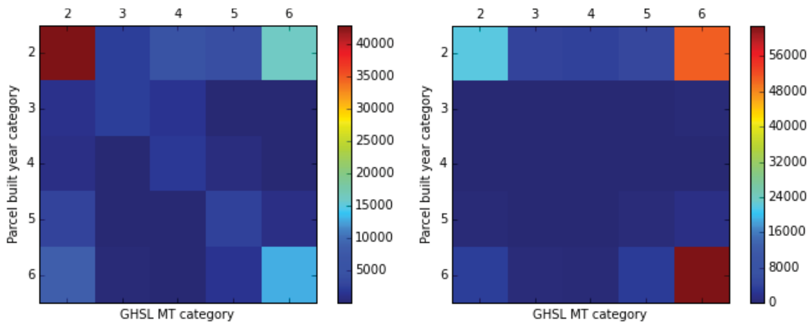


Figure 4: Overall confusion matrices for the urban study areas Madison, Wisconsin (left) and Milwaukee County, Wisconsin (right).

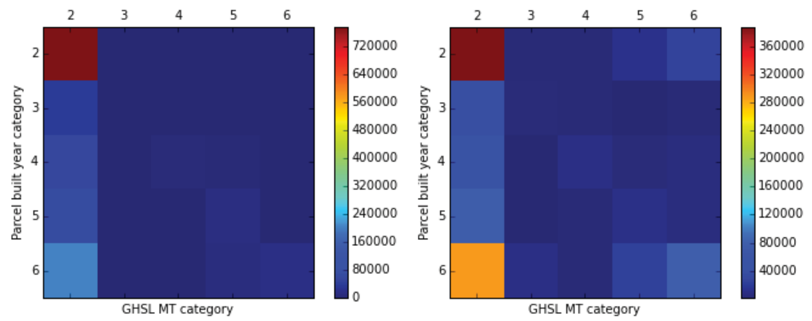


Figure 5: Overall confusion matrices for the rural study areas Boulder County, Colorado, and Baltimore County, Maryland.

Binary confusion matrices are used to derive agreement metrics comparing GHSL and parcel data for non-built-up labels (class 2) and built-up land in each epoch (classes 3-6). These metrics (Figures 6 and 7) also illustrate some interesting differences between rural and urban areas.

User's Accuracy (i.e., a pixel labelled class 4 in GHSL is also labelled class 4 in the parcel reference data) in rural areas increases over time and is higher for the built-up classes when compared with urban areas. Pixels of higher development intensity are more reliably detected as built-up in GHSL, and these locations are most likely within residential parcels in rural settings.

Producer's Accuracy (a pixel of class 4 in parcel data is classified as class 4 in GHSL) increases slightly in both settings over time but is much lower in rural areas due to the overestimated built-up land in parcel data. Overall agreement (PCC) decreases towards more recent epochs due to an accumulation effect of disagreement in earlier epochs. Interestingly, Kappa, which accounts for chance agreement and is more conservative than PCC, increases over time in rural settings but decreases in urban areas. Possibly, this reflects higher detection rates in rural areas with improved technology, and at the same time a cumulative effect in urban areas similar to PCC.

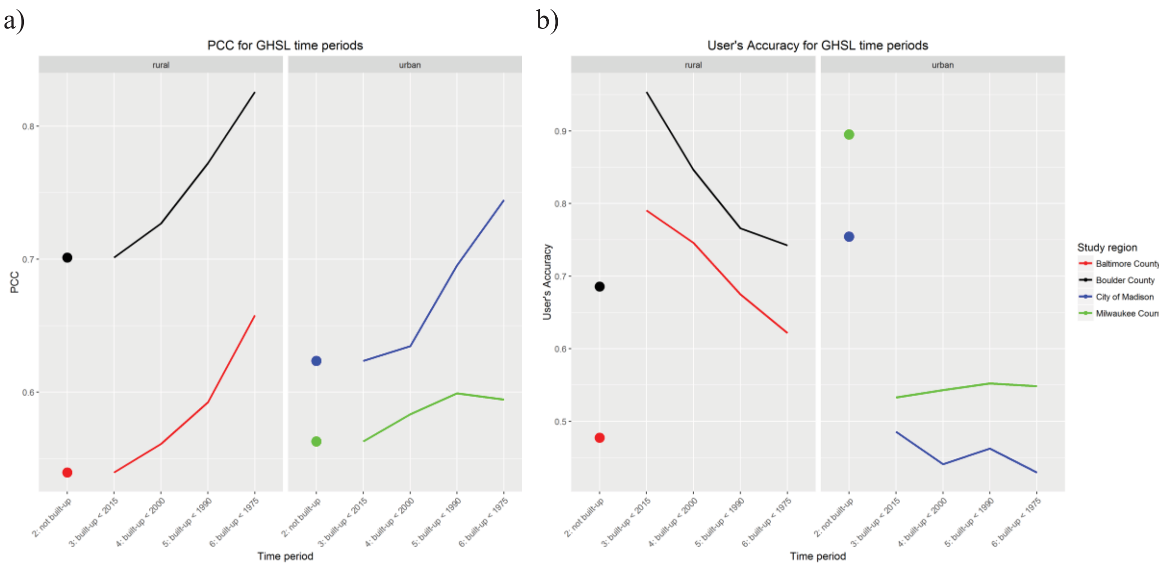


Figure 6: Trends in agreement metrics for urban and rural areas: a) PCC, and b) User's Accuracy.

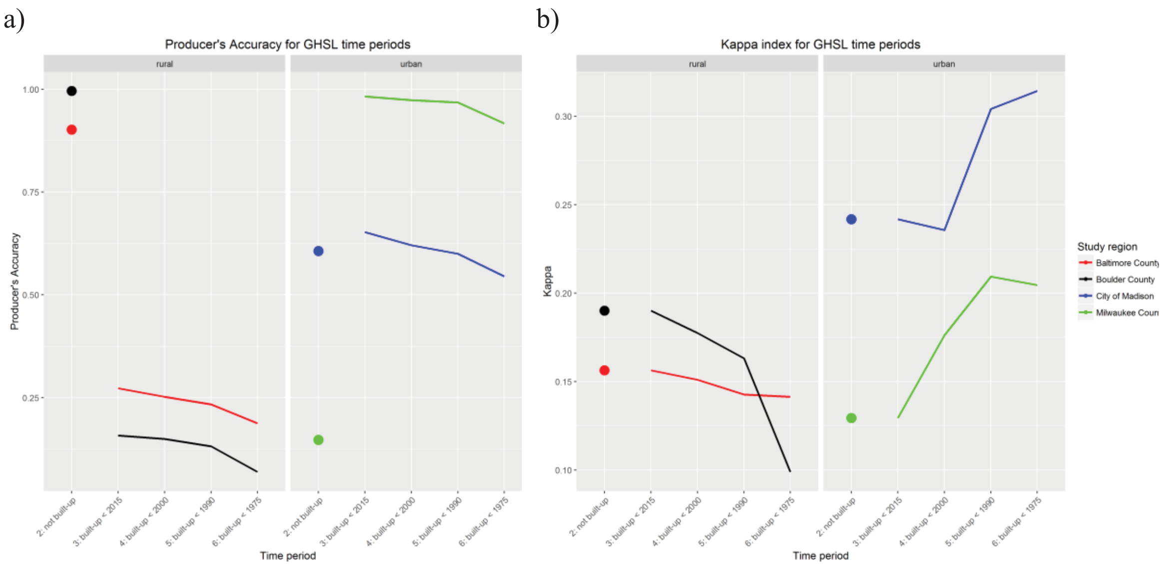


Figure 7: Trends in agreement metrics for urban and rural areas: a) Producer's Accuracy, b) Kappa.

IV DISCUSSION

Measuring the agreement in built-up land labels between publicly available parcel data and GHSL over time allows to investigate the usefulness of parcel data for evaluation of GHSL classes in rural and urban settings. While the built-year attribute provides a unique key feature for spatio-temporal evaluation purposes, the results show that the use of parcel data may bias the evaluation results due to inherent mismatches between the two data sources. Higher degrees of disagreement become evident in rural areas, where the residential parcels can be very large. Thus in order to establish robust protocols for thorough evaluation of GHSL the spatial integration of building data, which are becoming increasingly available (e.g., LiDAR derived), will be tested to identify built-up areas within parcels more precisely thus creating more reliable reference datasets. Such an evaluation will also need to address uncertainty due to spatial offsets between datasets and the inherent uncertainty in the temporal information (e.g., (i) due to tear-downs and rebuilt structures, not reflected by the built-year attribute, (ii) the exact timestamp of an image and the assigned nominal class). Such an evaluation procedure will develop a broader understanding of the uncertainty across space and time in GHSL built-up area labels and inform the future user community about fundamental quality aspects if GHSL is applied to similar settings in other countries where no reference data are available. In future steps, the study area will be further extended, alternative criteria to differentiate urban vs. rural settings will be examined, and the appropriateness of the accuracy metrics employed will be critically reviewed.

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