

Attachment 5 – UEI Geospatial Assessment Methodology

Comparing randomly selected households in the impact areas and control areas of cities required a robust and well-thought-out geospatial analysis that involved several steps, each step generating a map (or maps) for each of the 18 participating cities. While the household survey was eventually carried out in 8 cities, the final decision on which cities to survey depended in part on the geospatial analysis and in part on the security situation prevailing in each city at the time of the survey. The geospatial analysis was thus undertaken to some degree in all 18 cities. It involved nine steps:

- Mapping Urban expansion 1990-2022.
- Identifying the expansion area built during the 2013-2022 period.
- Georeferencing and digitizing the approved urban expansion and arterial road maps prepared by municipal officials.
- Creating a spatial inventory of all the existing road rights-of-way that were 10 meters wide or more in the entire 2013-2022 expansion area and up to 1 kilometers beyond. These roads have following information attached:
 - Road width into three categories; 10-15, 15-25 and 25+ meters
 - Roads existing before 2013 and new roads that were build or widened between 2013-2022
- The condition of the road surface in four categories: (1) opened; (2) laterite; (3) partially paved (only some of the width of the right-of-way is paved and the rest is open); and (4) fully paved (10 meters or more in width is paved)
- Mapping the new arterial roads in the 2013-2022 expansion area.
- Mapping land use (formal and informal residential, non-residential) in the 2013-2022 expansion area.
- Identifying impact and control residential areas in the expansion area.
- Generating a sequence of quasi-random Halton Points in the impact and control areas, to identify household to be interviewed.¹

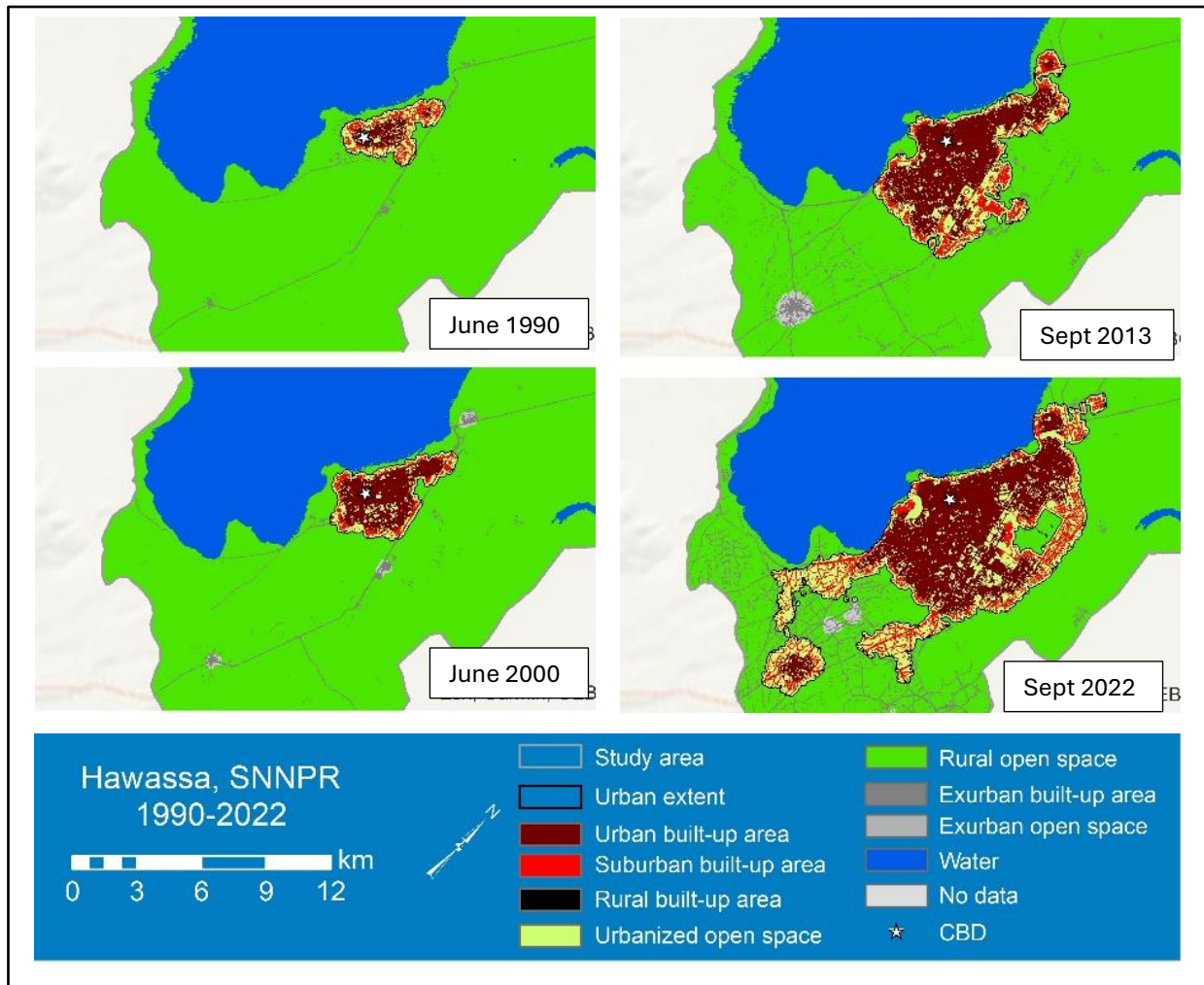
With the support of a Geospatial Consultant (Mumbai-based “Urban Observatory”), satellite imagery for each city from about 2013 and 2022 was assessed to identify: (a) limit of the built urban area in each period, with the “urban expansion area” defined as the difference between the two; (b) new arterial roads (minimum 15 meters width roadway) providing connectivity for expansion area to the pre-existing core urban area; (c) “impact” residential areas developed between 2013 and 2022 within 500 meters of the new arterial roads and

¹ A Halton sequence is a statistical procedure that generates a set of points in space that is deterministic—i.e. it generates the same set of points each time from the same starting point—but, for most purposes appears to be random. The points are more uniformly distributed than a random distribution. [Halton, J. (1964), Algorithm 247: Radical-inverse quasi-random point sequence, Communications of the ACM, 7(12):701.

“control” residential areas at least 500 meters from new arterial roads and at least 300 meters beyond the “impact” areas; and (d) a quasi-random set of Halton Point coordinates within each “impact” and “control” area to serve as enumerator starting points for selection of 250 households to be interviewed in each area.

Mapping urban expansion 1990-2022

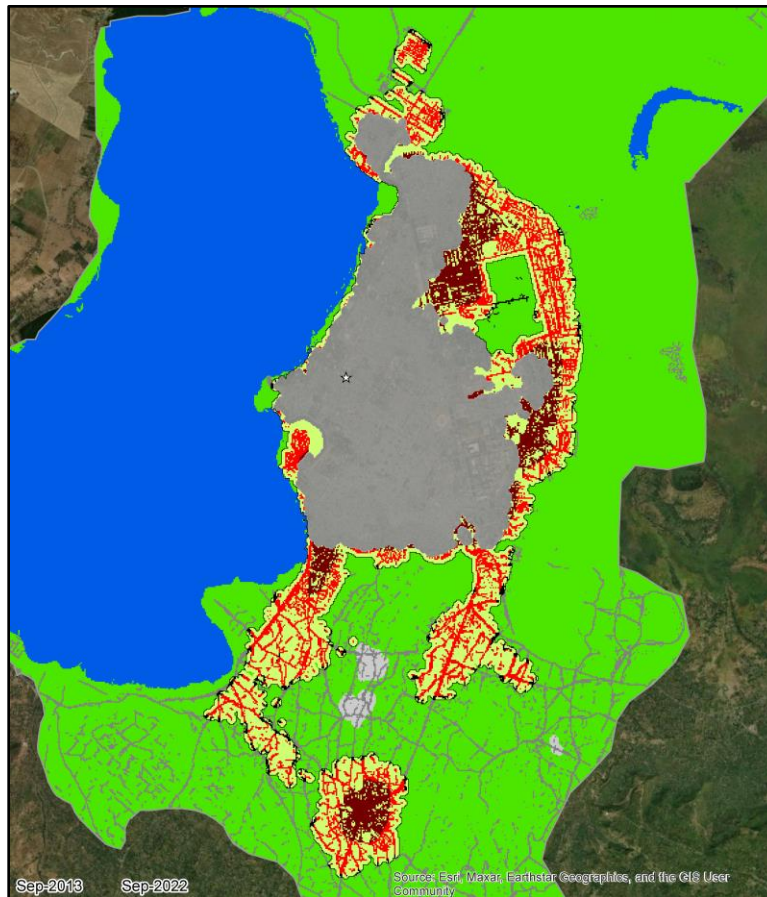
The Urban Observatory team carried out urban landscape analysis via classification and analysis of medium resolution Landsat satellite imagery. The analysis focused on urban areas’ physical extents, their attributes, and changes over time. It emphasized the need to recognize the land conversion to urban use. The resultant analysis resulted in maps and metrics for each city for four time periods: 1990, 2000, 2013, and 2022. This is illustrated in the maps for Hawassa below. These included urban extent, built-up area, saturation, compactness, and the shares of the added built-up area in infill, extension, leapfrog, and inclusion of existing settlements. These maps provided information on the annual rate of urban expansion in every decade during the 1990-2022 period. While not of immediate use for the household survey, these maps provide an essential input to the survey, as described in the next paragraph.



Tracking urban expansion in the 18 participating cities, an example: Mapping urban expansion in Hawassa, SNNPR, Ethiopia, 1990-2022

Identifying the expansion area built during the 2013-2022 period

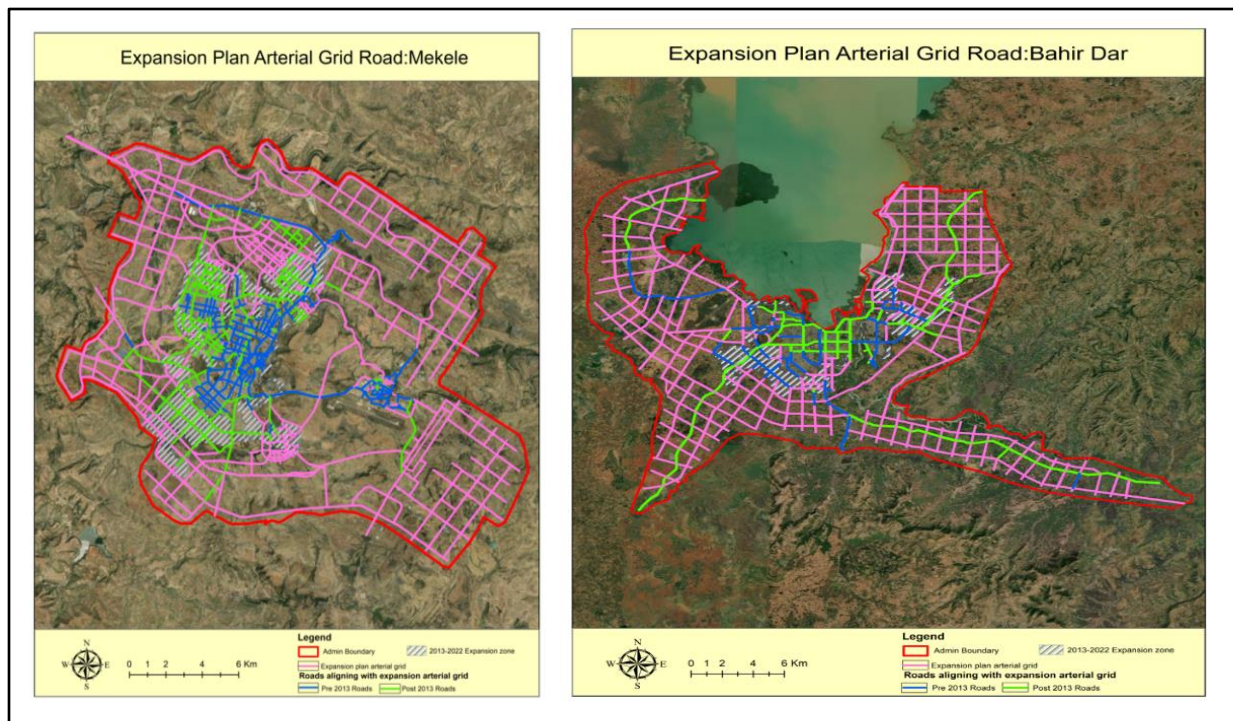
The urban extent maps for each of the 18 cities for the two periods circa 2013 and 2022 were used to identify the 2013-2022 expansion area of the city, essentially the area obtained by subtracting the 2013 area of the city from its 2022 area. The map of the expansion area of Hawassa—essentially the area within which the household survey was to take place—is shown in the map below.



Identifying the expansion areas of the 18 participating cities, an example: The expansion area of Hawassa, Ethiopia, during the 2013-2022 period. (The masked out central area in light grey is the urban extent before 2013. The outer dark grey areas are exurban areas and rural roads.)

Digitizing and georeferencing the approved urban expansion and arterial road maps prepared by municipal officials

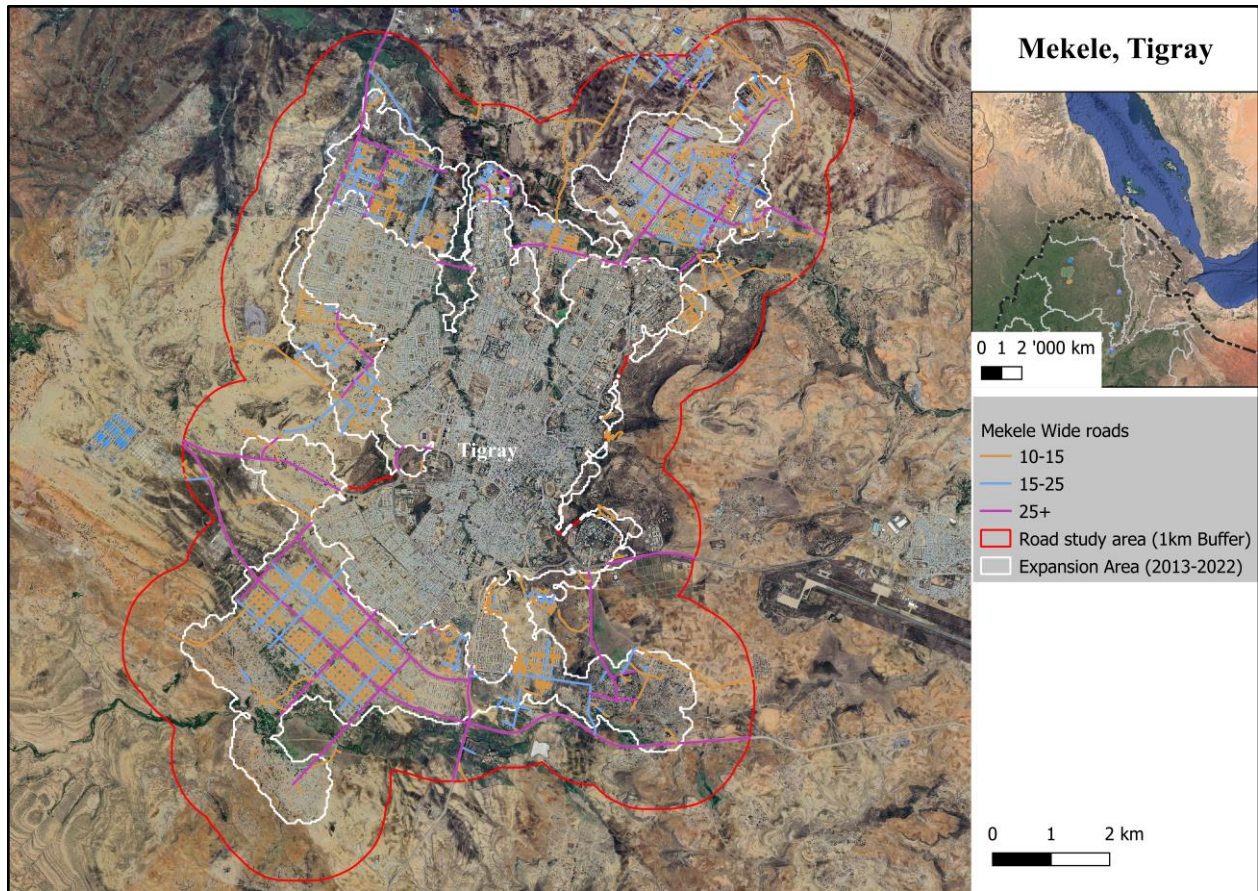
All of the cities participating in the UEI prepared maps of their 30-year expansion areas in 2013-2014, which included layouts of their projected arterial road grids. These maps were obtained by the Urban Observatory, digitized and geo-referenced, with the prospect of using them to identify which of the roads built during the 2013-2022 period were, in fact, included in their 2013-2014 urban expansion plans.



Two examples of urban expansion plans and their corresponding arterial road grids prepared by municipal officials in Ethiopia in 2013-2014: Mekelle and Bahir Bar, Ethiopia.

Mapping the new arterial roads in the 2013-2022 expansion area

In each of the 18 participating cities, the Urban Observatory team identified the new ‘wide’ roads built in the expansion area during the 2013-2022 period: roads that were 10-15 meters wide, roads that were 15-25 meters wide, and roads that were more than 25 meters wide. This was a crucial step that, together with the arterial road maps in the urban expansion plans, helped identify new arterial roads. The map of the wide roads in the expansion area of Mekelle is shown in the image below. This map, like the maps for the other participating cities, allowed us to identify the new arterial roads.



Identifying wide roads in the 2013-2022 expansion area of Mekelle, Ethiopia.

Mapping land use (formal and informal residential, non-residential) in the 2013-2022 expansion area

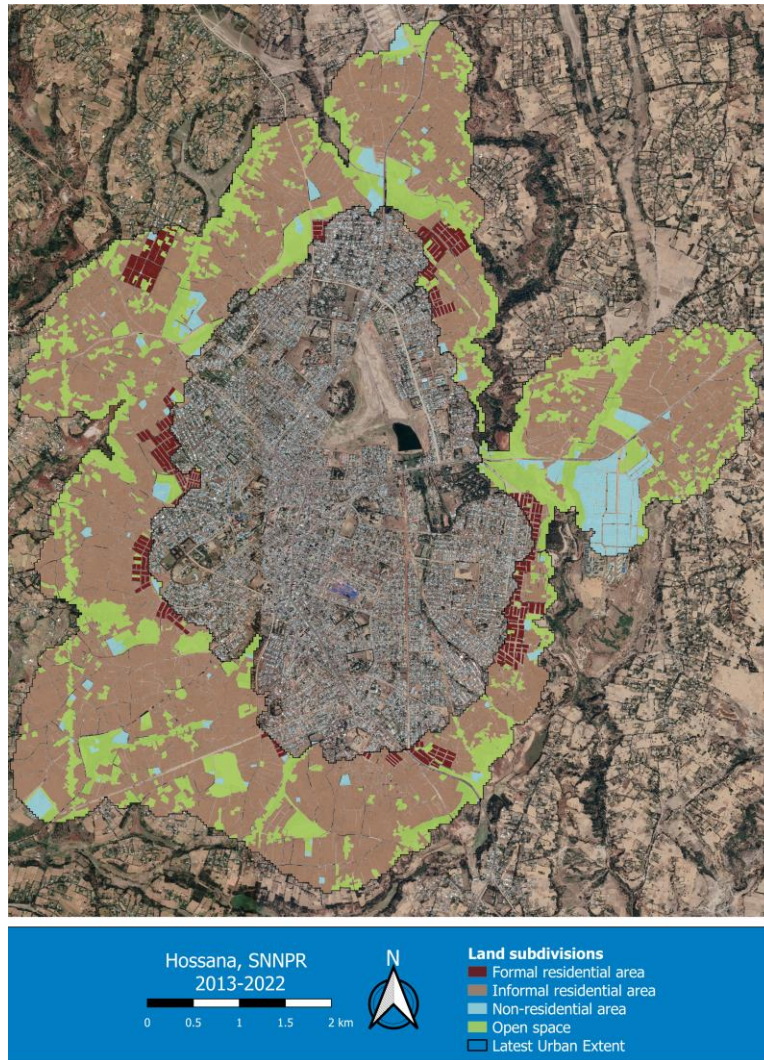
As noted earlier, the impact areas and the control areas are expansion zone residential areas that are within or beyond a certain distance from new arterial roads. Determining these areas required classifying the land use in the expansion areas of participating cities into formal residential, informal residential, non-residential and open land use. The following land use types were considered:

- Open space includes open countryside, forests, cultivated lands, parks, vacant lands that have not been subdivided, cleared land, and water bodies: seas, rivers, lakes, and canals;
- Non-residential areas include all built-up areas, both public and private, that are not in residential use;
- Informal land subdivisions are areas that have been subdivided for urban use, but that lack visible evidence of conformity to land subdivision regulations such as regular plot dimensions, paved roads, streetlights, or sidewalks. This may include

are areas with irregular layouts that were clearly not subdivided or laid out before residential construction took place. That said, structures in these informal land subdivisions, although different in size and form, are typically laid out along straight or almost-straight roads, with regular intersections and standardized widths. Blocks are also regular or semi-regular in size and shape, when topography permits;

- Formal land subdivisions are similar in layout to informal layouts, but exhibit a higher level of regularity, a higher level of provision of infrastructure, and better connections to existing roads. All roads have regular consistent width for an area to be classified as a formal land subdivision. Sidewalks and streetlights are often visible as well;
- Road space includes the rights-of-way of lanes, streets and roads, both paved and unpaved, containing both the area that is currently in use and any lands that are clearly reserved for future use.

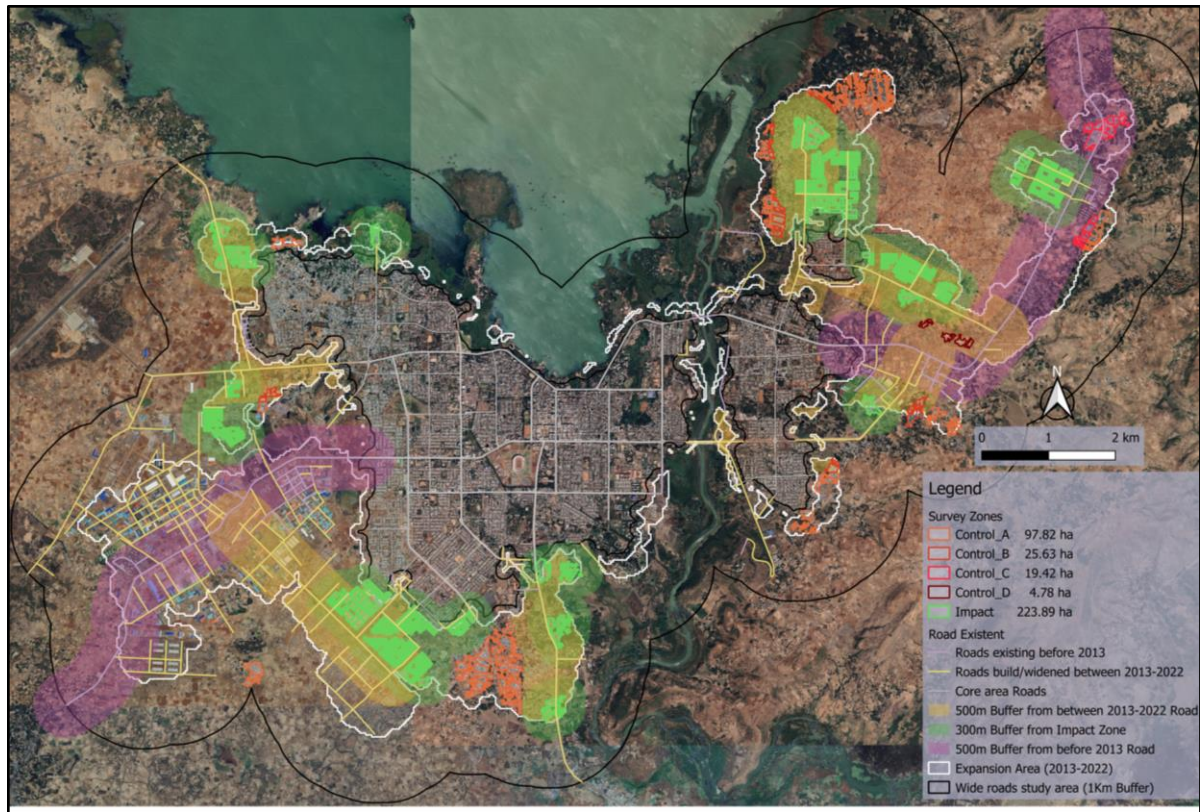
To identify the elements of the land use layer, the Urban Observatory made the distinction between block space and road space. Road space consists of all land that is currently or potentially used by either pedestrians or vehicles to travel from one place to another. This informed the identification of the rights-of-way of streets and roads, containing both the area that is currently in use and any lands that are clearly reserved for future use. All of these areas constitute road space. Block space consists of all other uses, including open space and off-street parking areas. In other words, all space that is not road space is block space, and all block space is assigned a land use. Block space is subdivided into units identified as blocks. Individual blocks are areas that are continuously bounded by roads or vacant open spaces (for instance, a block at the edge of a built-up area that borders on farmland). Any given block might contain several different land uses (say, Informal residential on one end, non-residential in the middle, and formal residential at the far end). The land use map of the expansion area of Hossana is shown in the image below.



The identification of formal residential, informal residential and non-residential land use in the expansion area of Hossana, Ethiopia.

Identifying impact and control residential areas in the expansion area

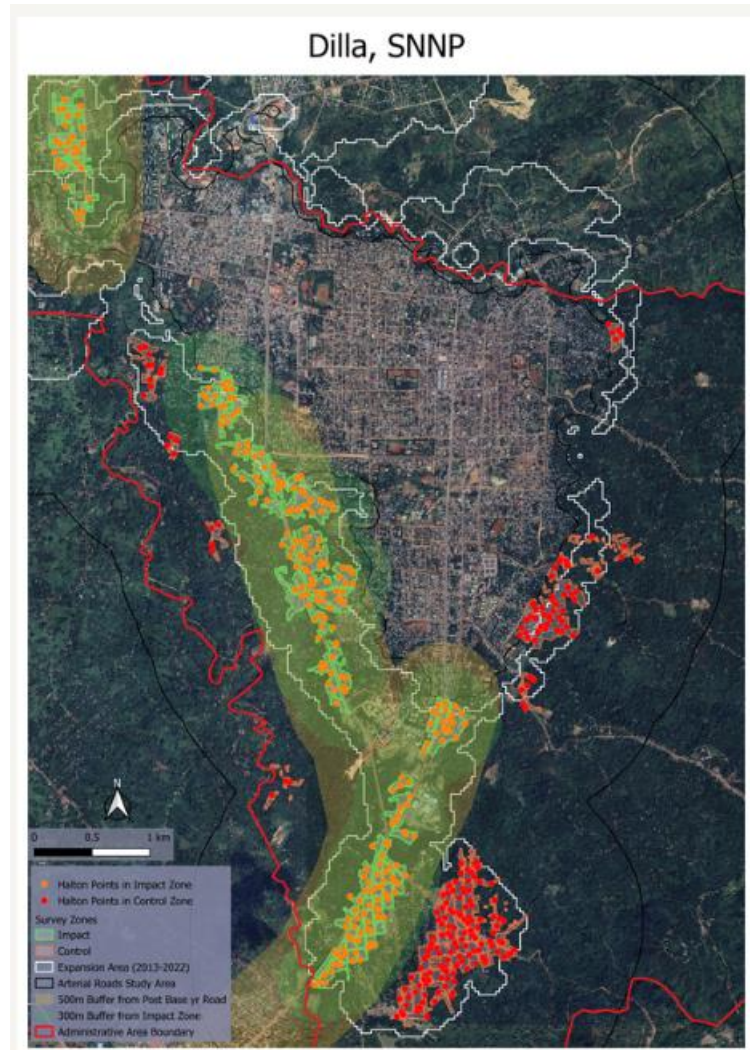
Given the arterial road maps and the land use maps, the Urban Observatory could identify impact areas and control areas. Impact areas were residential areas in the 2013-2022 expansion areas that were within walking distance (500 meters) from arterial roads. Control areas were residential areas in the 2013-2022 expansion areas that were more than 500 meters away from arterial roads and at least 300 meters from impact areas. The impact and control areas of Bahir Dar are shown in the image below.



The impact and control areas in the expansion area of Bahir Dar, Ethiopia.

Identifying a sequence of quasi-random Halton Points in the impact and control areas, to identify household to be interviewed

A Halton sequence was used to generate a sequence of points in the expansion areas of the participating cities, with the idea that the households to be interviewed were those in houses that were closest to a given point in the sequence. A set of Halton points for Dilla, Ethiopia, is shown in the image below.



A sequence of Halton points in the study area of Dilla, identifying points in the impact and control areas within its urban expansion zone that were used to select households for the survey.

Potential confounding factors and limitations for separate consideration

City conditions varied significantly: differing degrees of UEI political support and implementation; differing effects of political conflicts and displacement; and varied economic conditions and development.

Depending on the actual geography and distribution of expansion area housing, in some cities there was a need to relax the standard distance requirements between arterial roads, impact and control areas, in order to obtain sufficient control samples.

The relative precision in the satellite imagery analysis may actually obscure conditions as lived by residents on the ground, reducing somewhat the meaningfulness of the distinction between “impact” and “control” effects, since areas might be classified differently from the perspective of local residents. There were households in control areas with good access to major roads, while some important arterial roads might have still been under construction. This is confirmed by responses to a survey question as to whether the respondent lives “in expansion area served by arterial roads,” for which roughly two-thirds of responses correspond on both variables and one-third do not; the respondent-reported condition provided somewhat sharper distinction with some correlations (eg, housing conditions, travel duration). Recognizing this difference in perspective, in some cases the evaluation considers the household respondent perspective on the presence of an arterial road in their area.

<div> <div>Table 1</div> <div>9. Classification of Household location</div> </div>			
		Impact area	Control area
12. Is this house in expansion area served by arterial roads?	No	35.26%	64.74%
	Yes	61.75%	38.25%
Total			

Finally, some neighborhoods in Hawassa and Dilla originally included were removed due to political sensitivities related to the creation of new states from the previous Southern Nations, Nationalities and Peoples (SNNP) State. This required adjustment to the sampling frame for both impact and control areas.