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Beyond Urban and Rural: Exploring Form, Accessibility, and Interconnectivity in Global Urban Classifications

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Abstract

Sustainable development increasingly hinges on recognizing both the nuance of urban form and the interconnections linking settlements into systems. We compare three global geospatial approaches transcending the urban–rural dichotomy—Degree of Urbanization (DEGURBA), Urban–Rural Catchment Areas (URCA), and Multi-Tier City–Regions (MTCR)—and examine how they relate form, accessibility, and function at system scale. Highlighting the importance of peri-urban areas, small and intermediate cities, and multi-tier connectivity, these approaches challenge institutional structures organized around an urban–rural divide. We conclude by outlining four research frontiers.

Introduction

Urbanization profoundly impacts sustainability across scales, with effects extending beyond traditional urban boundaries¹. While urban science has progressed, current approaches often fail to capture the complexity and interconnectedness of modern urbanization patterns. The increasing connectivity among urban centers and with rural areas through infrastructure networks² demands new analytical approaches that move beyond traditional urban-rural classifications. Zhou and co-authors³ synthesize existing frameworks and emphasize the need for a comprehensive urban systems science that addresses the joint social, ecological, and technological nature of these systems.

Place-based approaches that ground abstract concepts in specific contexts, facilitate understanding of how local interventions interact with regional systems. These emerged as a key focus in 2015-2016 when finalizing the UN Sustainable Development Goals and the New Urban Agenda⁴. While valuable, place-based research—including recent advances in defining functional urban areas using mobile phone data⁵⁻⁷—needs to be integrated within more comparative and systematic approaches to generate globally applicable insights. For example, Rozenblat and co-authors (2018)⁸ provide a unified classification for the evolution of urban systems in a comparative framework across countries in different continents arguing that cities need to be understood not simply as individual entities but as parts of broader systems of cities at different spatial scales.

In this Perspective, we show how systematic approaches can be implemented at a global scale that also maintain an information content typical of place-based approaches. The narrative moves away from the traditional rural-

urban categorization, long recognized as limiting across socioeconomic disciplines^{9–14}. It discusses and compares applications of systematic rural-urban continuum approaches, such as the widely-used Degree of Urbanization (DEGURBA), with the Multi-Tier City–Region approach that also takes into account inter-urban connectivity.

We build on the continuum of urbanity framework^{3,15} that captures connectivity within and between urban areas, as well as the intersection of urban and rural areas, and reflects the four characteristics of urbanized areas, namely complexity, dispersion, connectivity and diversity¹⁶. Our work is also aligned with the literature on ‘rurbanism’ and ‘rurbanity’, which goes back nearly a century, and that can be considered as focusing on environmentally, socially and culturally productive co-presence of urban and rural elements and practices^{17,18}.

We explore how recent global geospatial datasets transcending the rural-urban dichotomy can translate abstract concepts into measurable patterns. This practical application bridges theoretical frameworks and actionable insights for urban planning and regional development.

These conceptual foundations align with emerging frameworks for understanding regional systems, particularly the concept of “metacities”—urban mosaics of patches differentiated by their interacting biophysical, social, and technological components³. This aligns with calls for a new Global Urban Agenda that adopts “a spatial or place-based approach to planning and development; looking at the intersecting needs of different geographies” in an interconnected world⁴. To address 21st-century challenges, urban science must develop theoretical and methodological approaches that capture the complexity, connectivity, and dynamics of city–regions. Expanding the boundaries of urban science is essential for creating effective, equitable, and sustainable strategies for regional development and governance.

Different geospatial representations of the continuum of urbanity

Recently, important advances were made in developing a methodology for delineating urban and rural areas for international and regional statistical comparisons. Figure 1 presents these developments illustrating how population is classified, starting from rural vs. urban, where the size of the spheres resembles the population in a category (Figure 1, Panel A).

In 2020, the UN Statistical Commission endorsed the Degree of Urbanization (DEGURBA), introduced by Dijkstra & Poelman¹⁹, which classifies the entire territory of a country across a one-dimensional rural–urban continuum based on population size and density (Figure 1, Panel B). The classification system consists of three classes – cities, towns and semi-dense areas, and rural areas – and three subclasses for the towns and semi-dense areas as well as three subclasses for rural areas.²⁰ The classification is based on population of contiguous cells and population density therein. Results for DEGURBA indicate that for 2015, 48% of the global population was urban, 28 percent in towns and semi-dense areas, and 24% rural (Figure 5 in Dijkstra et al.²¹).

Another approach providing a global mapping of the rural–urban continuum is Urban Rural Catchment Areas (URCA) based on the Global Human Settlement Layer²². Similarly to the DEGURBA classification, it places urban centers on a gradient based on population size and density. But it also adds a second dimension: rural locations are assigned a gradient of their own, using the shortest travel time to urban centers of various sizes as a proxy for the ease in accessing goods, services and employment opportunities (Figure 1. Panel C). Thus, the URCA dataset disaggregates rural areas into multiple categories; distinguishing, for example, between locations that are less than 1 hour from an urban center (peri-urban) and those that are farther away, requiring 1-2 hours or 2-3 hours travel time. The approach finds that 92% of the global population is urban or lives within 1 hour travel

time of an urban center²². A hierarchy of urban centers by population size (largest to smallest) is used to determine which center is the point of reference for a given rural location: proximity to a larger center dominates over a smaller one in the same travel time category. For each location it thus distinguishes, for a given travel time cutoff, the population size of the largest accessible urban center among the following categories: towns (20,000-50,000), small cities (50,000-250,000), intermediate cities (250,000-1,000,000), and large cities (> 1,000,000). The thresholds for this categorization were chosen to align as much as possible with commonly used ranges (adopted by the UN, OECD, and the European Commission^{20,23,24}). To illustrate the relevance of this distinction, in low-income countries, 64% of people live in small cities/towns or their catchment areas; instead in middle and high-income countries, it is 28–39%, reflecting easier access to larger urban centers thanks to better infrastructure²².

While valuable in providing additional information compared to the DEGURBA, the URCA approach links locations to a single urban center of reference, ignoring that a location may have multiple urban centers of reference for different activities. Furthermore, in both approaches a location is not put into a clear relation with the rest of the locations in its surroundings: every location is like an island unto itself with, at best, information on whether it is in the vicinity of an urban center and the size category of the largest urban center it can reach withing a given travel time cutoff, but nothing more specific. To understand connectivity there is a need to organize cells into a spatial network. The network should represent mosaics of patches differentiated by their link to different dimensions, such as services, employment opportunities, and environmental amenities. Researchers have introduced a spatial network approach based on classifying built-up land surface as nodes –urban centers– and the edges being defined as connecting neighboring urban centers within a pre-specified search radius in terms of distance or travel time^{25–27}.

The multi-tier city–region (MTCR) takes a different approach, introducing the concept of locations —rural or urban— potentially accessing multiple urban tiers. This enables the analysis of both relationships between urban centers and peri-urban and rural areas, as well as intercity relationships.²⁸ In MTCR, continuous grid cells of the GHSL-SMOD dataset²⁹ classified as urban center, dense urban cluster, or semi-dense urban cluster are used to identify *urban centers* that provide various activities (e.g., education, healthcare) for both residents and surrounding populations. Similarly to the URCA, it defines four *urban tiers* (U1-U4) for these urban centers based on their population: towns (20,000-50,000), small cities (50,000-250,000), intermediate cities (250,000-1,000,000), and large cities (> 1,000,000). To reduce sensitivity to differences across population data sources, it uses four existing gridded population datasets for the year 2020 in combination to determine urban tiers^{30–33}. This categorization results in 18,619 towns, 9,440 small cities, 1,538 intermediate cities and 482 large cities in the year 2020. In parallel, it assumes four *activity tiers* (T1-T4), ranging from basic activities (e.g., groceries, primary schools) to higher-end activities (e.g., international airports, specialized hospitals), with increasing specialization and decreasing frequency of individual use (see Table 1 in Cattaneo et al for complete list of activities²⁸). The term ‘activities’ refers to services and employment opportunities located in urban centers. Assuming that the diversity of activities increases with population size, each urban center is considered to provide the full set of activities corresponding to its urban tier, as well as those of lower tiers.

<<Figure 1 approximately here >>

In Figure 1 Panel D this is represented by four layers in 3-D with the first one representing the population distribution based on locations' closest urban center, while the other three layers capture the subset of population that has access to two, three, and four urban tiers within a specified travel time (y-axis). The innovative approach of city-region patches, which provides a more nuanced framework for analyzing how locations (urban or rural) are embedded within systems of multiple urban centers, is illustrated by the red line in Panel D of Figure 1, indicating that there are locations that are in a town (contributing to size of purple sphere), but within 1-2 hours of a small city (grey circle on second plane), and slightly further away (but also within 1-2 hours) from an intermediate city (grey circle on third plane) and 2-3 hours from a large city (grey circle on fourth plane). This is only one example of the many inter-connections that are taken into account in the approach, which cannot be represented visually in a manageable way. There are potentially 192 such connections considering four urban tiers and three travel-time cutoffs. Having only one urban center of reference, the URCA can be considered as a limited case within the broader multi-tier framework presented in Panel D of Figure 1. The difference in population distribution (size of the spheres in Figure 1) between URCA and MTCR indicates that there are many towns and small cities that are closest to peri-urban locations but that are not visible in the URCA dataset because only the largest urban center within a travel time cutoff functions as the urban center of reference. This is reflected in the finding of these two approaches with URCA showing 34% of people living in or gravitating around towns and small cities while in MTCR this increases to 55% of the global population^{22,28}.

Results from MTCR indicate the extensive interconnectedness among urban centers and their surrounding areas, showing that a significant portion of the global population has access to multiple urban tiers within practical travel times: in 2020, 41% of the global population had access to multiple urban tiers within 1 hour travel time and 57% within 2 hours²⁸. Of relevance for commuting, the city–region approach, through aggregating patches associated with different urban centers, identified 4,210 primary and 25,869 secondary city–regions with an urban center within a 1 hour travel time for all locations within their catchment area. The distinction between primary and secondary city–regions is that in secondary city–regions catchment areas of urban centers overlap with that of larger centers, while in primary city–regions that is not the case (see Table 1 in Cattaneo et al.²⁸). The MTCR dataset also highlights the importance of intermediate cities, finding that even though only 9% of the global population lives in intermediate cities, another 24% gravitates around them within 1-hour travel time (based on Figure 1 in Cattaneo et al.²⁸). These findings are in agreement with earlier analyses that take a systemic perspective and mention the importance of emerging cities based on a combination of top-down policies and bottom-up developments leading to city–regions³⁴. MTCR data provide a good snapshot of city–region systems because it puts in relation smaller and larger urban centers.

Information complexity and analytical pathways in interconnected systems

The evolution of these approaches goes in the direction of capturing the complexity of the interconnections between urban, peri-urban and rural locations. Better capturing system structure requires processing and storing more information. To understand this evolution one can take as benchmark the traditional rural-urban dichotomy, which contains only one bit of information for any given location: it is a binary classification, a grid cell is either rural or urban, no other information is provided. The DEGURBA adopts 7 categories in classifying grid cells, which requires 3 bits to store the information. The URCA approach, by adding a second dimension of shortest travel time to urban centers of various sizes, classifies grid cells into 16 categories, requiring 4 bits of information.

The MTCR approach provides an improvement that goes beyond the incremental improvements of the DEGURBA and URCA, relative to the urban-rural dichotomy. It creates a tessellation of all locations that can access a subset

of urban centers within a given travel time. The tessellation is provided by *city–region patches* describing the spatial distribution of multiple levels of activities (assumed to be available based on different population sizes of urban centers) and by which urban centers they are provided within a specific travel time cutoff²⁸. Urban center IDs of each city–region patch grid cell for four different activity levels are merged into a patch ID by using a variable-bit encoding method, which results in unique IDs for each unique set of urban centers providing different levels of activities. Land-based locations worldwide are divided among about 100,000 unique patches for each travel-time cutoff. Taking the number of patches as a reference, one needs a minimum of 17 bits for storing the classification information. Since the city–regions dataset also stores information about the urban center IDs, i.e. unique cell values associated with a patch as well as tracing back each patch to the related urban center IDs, we actually need 52 bits for each travel-time cutoff. Compared to the DEGURBA and URCA, which requires 3 and 4 bits respectively, the amount of information stored in the city–region dataset is orders of magnitude greater than what was previously available.

The information contained in the MTCR dataset can be represented in different ways. It relies on the assumption that each urban center is considered to provide the full set of activities corresponding to its urban tier, as well as those of lower tiers. For example, a small city (U2) offers both T1 and T2 activities. This allows to organize information into *urban catchments*, *city–region patches*, and *city–regions*. For each activity tier it provides, an urban center has a corresponding *urban catchment* defined by a specific travel-time cutoff, which includes all locations within the travel-time cutoff provided they are not closer to another center providing the same activity tier. Thus, a small city has both a T1 and a T2 catchment within, for instance, a one-hour travel time, which may overlap or differ, depending on the presence of other nearby centers and their urban tiers. In the MTCR approach, travel-time cutoffs of 1, 2, and 3 hours are considered. Overlaying catchments of all activity tiers for a specific cutoff and identifying their unique combinations produces *city–region patches*. Each patch represents an area served by a distinct set of urban centers for different activity tiers. For example, one patch may have access to T1-T3 activities, with T1 provided by a town and T2-T3 by an intermediate city, while another patch may access the same activities solely through the intermediate city. The collection of all patches associated with a given center for a specific travel-time cutoff forms its *multi-tier city–region*. For instance, the one-hour city–region of a small city consists of all patches where that city provides T1 or T2 activities. It is by tracking the nearest centers across activity tiers, along with their travel times, that the MTCR approach generates a global tessellation of locations. For any location, the tessellation shows which urban centers are accessible within the specified cutoff for what kinds of activities and how they are connected to each other, allowing detailed relational analyses not only among interconnected urban centers, but also including their peri-urban and rural surroundings.

Depending on the type of research questions, the MTCR data can be used in different ways. The most straightforward, at a local level, is to observe the city–region patches and urban catchments for different levels of activities. Another possibility is to focus on the rural dimension and define functional rural areas (FRAs) along the lines of what is being done starting from DEGURBA by the European Commission³⁵, which can be done by selecting city–region patches that match the properties defining a FRA. A more systemic approach can extract the information contained in the dataset to construct, from first principles, a full representation of the interconnected spatial network along the lines of what has been introduced by Esch and co-authors^{25–27}. This can be done by extracting which city–regions have overlapping areas for a given travel time. If two city–regions have an overlapping area, for travel time less than t^* (e.g. 1-hour for commuting) then we can state they are connected because there are people who may rely on both the urban centers associated with the two overlapping city–regions. In a spatial network representation the urban centers are the nodes and the

connection between the two is an edge where the weight may be assigned based on the population that lives in the overlapping area (as a measure of the relevance of connectedness). The spatial network that would result would be one that is consistent with the hierarchy of settlements of Central Place theory, resulting in a sub-graph for every primary city–region (since city–regions providing a same urban activity tier cannot overlap in the MTCR framework. Since the MTCR dataset is global, this type of network could be built quite easily for all countries in the world, which currently has yet to be done.

A visual comparison of the three approaches helps understand their potential applications

A comparison of the spatial representation in classification adopted by the three approaches highlights some important differences (Fig. 2). One such difference is the increasing level of information being mapped, as expressed by the increasing complexity of the legend. Looking at London and its immediate surroundings we find a stark contrast between the degree of urbanization, which has a substantial share of area (i.e. grid cells) around London as low- or very-low density rural areas (Fig. 2a), whereas in the URCA classification these same areas are classified as being within 1 hour travel to a large city as their main characteristic (Fig. 2b). This points to how these datasets may be suited or not depending on the purpose of an analysis: for a study interested in green space in the greater London area, the DEGURBA may be a better fit than the URCA. However, if the purpose is to have a proxy for access to services or employment opportunities, then the URCA would prove more useful.

In this spatial comparison of London and its surroundings, the MTCR approach strikes a balance because it distinguishes patches based on their closest urban center and any higher tier ones in the same time travel interval (Fig. 2c). So, a location may be peri-urban relative to the London core, or to an intermediate urban center like Luton, or to a town within the greater London area at the same time. These locations would all be within one-hour travel of the urban core of London, but be quite different in practice because they don't rely only on London but also other centers, which is why they are represented in different patches. Furthermore, the MTCR approach, through its use of unique patches, keeps track for every location of its urban centers of reference. This can be important when combining with other spatial layers that may contain place-based information. For example, a small city may be home to a major university (e.g. Cambridge, Oxford, Reading) typically associated with larger urban centers. In the MTCR approach, it would be possible to 'tag' patches so that all locations that are within a certain travel time of that small city are 'elevated' to having access to a location with a major university and the associated services. This would not be possible with the DEGURBA or URCA datasets since in those approaches a grid cell does not have any information attached to it concerning the specific urban centers in its proximity except for those grid cells located within an urban core.

The comparison can be made also at a greater scale to see the difference at a more systemic level, including also broader rural areas (Fig. 2d-f). When examining a segment of Western Europe that includes Amsterdam, Brussels, London, Paris, and Rotterdam one can observe that for the DEGURBA the richest information is in the immediate surroundings of urban areas, but not much nuance is provided for rural areas: a rural location is classified solely based on its population density, independently of whether it is 45 minutes from Paris or 90 minutes to the closest town of 20,000 people or more. The URCA dataset does take these aspects into account, but in doing so, when it classifies a location, it only takes into account the largest urban center within the specified travel time (e.g. 1 hour or less) from that location. This tends to classify sizeable areas as peri-urban to large cities, even where populations routinely rely on small and intermediate cities, as is the case in Belgium and the Netherlands. In this respect the MTCR approach, although more complex, provides the nuance needed for many different kinds of analysis, highlighting how the areas around large cities are not defined solely by their access to those cities.

<<Figure 2 approximately here >>

The example presented in Figure 2 is illustrative of a highly connected system characterized by major transport infrastructure. A similar visual comparison is provided for Madagascar and its capital Antananarivo (Supplementary Information, Figure S1).

Opening new avenues of research in urban geography and regional planning

Next, we examine how the DEGURBA and URCA datasets have been applied in different disciplines, and how the MTCR dataset expands on those possibilities. The three global geospatial datasets are all available as open access.

The DEGURBA classification has been used to develop multi-temporal datasets³⁶ as well as for numerous analyses. For food systems it has been used to examine food insecurity in urban, peri-urban, and rural areas around the world³⁷, as well as examining household food consumption along the degree of urbanization in West Africa³⁸. Examples on the environmental side have looked at global population exposure to accelerated warming³⁹, estimating the extent to which buildings and wildland vegetation meet or intermingle⁴⁰ and impacts of urbanization on mangroves around the world⁴¹. Instead in terms of accessing services it has been used to classify geographic access to healthcare facilities in Sub-Saharan Africa⁴². An interesting application from an SDG perspective compared land use efficiency by degree of urbanization^{43,44}. Another common use of the DEGURBA is to simply focus on the urban element, and delineate cities in a systematic way across countries, which was previously difficult to do with country-specific definitions of what is urban^{21,45,46}.

The URCA classification has been applied in the context of food systems examining how population is distributed across catchment areas of urban centers of different sizes depending on countries' classification by food system typology⁴⁷. Another application was to examine food purchases across the rural–urban continuum for selected countries in Africa, focusing on ease of access to urban centers of different sizes³⁷. In Ethiopia it was used to examine differences in food access as a way of targeting infrastructure investments⁴⁸. The URCA was also used in the context of energy supply to examine energy supply among grid-electrified households living in rural and peri-urban regions around urban centers of different sizes⁴⁹. In the social dimension, in Nigeria it was used to examine the relationship between poverty and the size of the closest urban center as well as the travel time needed to reach it⁵⁰. In the environmental dimension, the dataset was used to quantify access to nature modeled as the number of urban and rural people within one hour of travel of natural and semi-natural habitats⁵¹, and in another study to examine the global population –broken down by URCA categories– impacted by air pollution using high-resolution estimates of air pollution⁵².

Similarly to DEGURBA, also the URCA classification is used at times to retrieve just a subset of the information it stores. For example, there are studies that use URCA data to examine issues according to urban, peri-urban, peri-rural, and rural areas^{53,54}, that do not use the information on the size of urban centers. Another study used it to examine the remoteness of rural towns in mine-town systems using the 'dispersed' and 'hinterland' categories of the URCA (located more than 3 h from an urban agglomeration of at least 20,000 people)⁵⁵.

As the above applications in different areas indicate, both DEGURBA and URCA provide clear opportunities for researchers interested in going beyond the traditional rural-urban dichotomy. However, even though they

introduce much needed nuance in classification, they fall short of taking a full systems perspective. The information contained in the MTCR dataset enables us to revisit longstanding theories of spatial organization around urban centers. The economic interactions of different locations over space were identified over a century ago^{56,57} and codified by Christaller⁵⁸ and Lösch⁵⁹ in Central Place Theory (CPT). Those theories, however, relied on simplifying assumptions necessary to come to a stylized geometric representation of how locations interacted. For example, Christaller assumed a limitless, uniform plain with equal soil fertility and resources, an evenly distributed population, and travel costs based solely on distance⁶⁰.

The MTCR dataset is based on the main premise of CPT, namely that a central place on one level provides a bundle of goods and services that is specific to that level, as well as all bundles that are specific to all lower levels⁶¹. However, the MTCR approach drops the simplifying assumptions of CPT thanks to georeferenced data and identifies primary and secondary urban centers and their interconnection based on travel time to access activities available in urban centers of different sizes and analyze them relying on observed population distribution. The MTCR dataset can be used to provide insights on the extent to which the hierarchy of settlements envisioned by CPT applies, and check what factors may affect the emergence of the structure predicted by CPT. As a preliminary analysis, it can be helpful to examine countries' share of population with access to multiple urban tiers.

<<Figure 3 approximately here >>

The MTCR dataset can be used to summarize population distribution information by using petal diagrams that present the share of population living in or within a certain travel time (1-, 2-, or 3-hours) to the closest urban center, as well as indicating the share of population that, within a given travel time, can also access urban centers in higher tiers, beyond the one they are closest to.

By illustrating for two low-income countries (Madagascar and Malawi) and two lower-middle income countries (Kenya and Nigeria), Figure 3 highlights –for the 1-hour travel time case– how interconnectedness among urban centers can vary substantially across countries. Summing the relevant petals, 55 percent of the population of Nigeria has access to multiple activity tiers within 1-hour travel time, while only 5 percent in Madagascar. The much lower number in Madagascar indicates that the hierarchical structure predicted by CPT has not materialized for Madagascar, whereas it has for Nigeria. Malawi has similar average per-capita income of Madagascar and yet the conditions were present to generate a multi-tier system along the lines of what is expected in CPT, with 41 percent of population able to access multiple tiers of activities within under 1-hour travel. Kenya has a similar share as Malawi (44 percent of population able to access multiple tiers); however, the tier profile is different in the two cases: Kenya expresses a strong connection between towns and small cities (18% of population), while Malawi has it between towns and intermediate cities (18% of population).

The MTCR data is open access⁶²; however, it is quite complex and difficult to handle without previous experience in geospatial analysis. The City–Region Explorer platform, launched in June 2025, overcomes these challenges by providing an easy to use web-based tool that does not require any geospatial expertise^{63–65}. Users can examine 30,000 urban centers as well as the interconnections between them and with their surrounding areas. The City–Region Explorer can replicate all figures & tables in the original MTCR paper, and users can go beyond replication and examine countries not highlighted in the MTCR paper. Similarly to the Urban Thematic Exploitation Platform

funded by the European Space Agency,⁶⁶ FAO's City–Region Explorer provides the capability for users to process and analyze data.

Broadening boundaries: Four research frontiers for understanding interconnected urban systems

The above serves as a very preliminary introduction to the opportunities the MTCR dataset provides for new insights on spatial organization of societies by advancing capabilities of existing datasets and revisiting longstanding theories using georeferenced data on urban centers, travel time, and population that were not available when theories such as CPT were developed nearly a century ago. We now present four potential applied research areas that are made possible by the global dataset on multi-tier city–regions.

Multi-tier city–regions can capture the complexity of economic interactions and dependencies between urban centers, and are relevant for labor markets, supply chains, and service provisions that transcend the boundaries of individual cities. They also are connected to the social ties that extend across urban and suburban areas, encompassing commuting patterns, migration flows, and cultural exchanges, which are crucial for understanding social cohesion and disparities.

1) Insights on how to improve infrastructure for better connectivity

In the previous section it was noted that many people do not have access to multiple urban activity tiers within 1-hour travel time. A first step in trying to address the situation is assessing whether marginal improvements in transport infrastructure could broaden access to higher tiers within 1-hour travel. To do so, we can observe the share of population that transitions between 1 and 2-hour travel time to a higher urban tier. Through marginal infrastructure improvements, transitions in the 1 – 2 hour range could be brought down to within 1 hour, making it a more commutable distance. However, this is only relevant if a substantial population resides within the 1–2 hour range that can benefit from activities provided by the higher urban tier, which the MTCR dataset directly reveals.

To illustrate this idea, we present in Figure 4 a heat map population matrix –for 4 countries– that looks at levels of activities reached when transition to higher urban tiers happens as a function of travel time. Darker cells indicate a higher share of the population transitioning. The diagonal of the matrix represents population that does not transition to a higher tier beyond a given travel time. Madagascar stands out for the high share of population that does not transition out of rural even with three hours travel time (dark cell on the diagonal). Improving transportation infrastructure at the margin could improve access from rural areas to towns and small cities, but not much more. On the other hand, Malawi and Kenya could improve access to intermediate cities (darker cells within the orange box). Nigeria, which was shown to have the most connected of the four national systems, would benefit from an improvement in infrastructure mostly in providing access to the highest urban tier for population that already has access to an intermediate urban center. From such an analysis, one can come to a preliminary conclusion that marginal investments in infrastructure may make sense in Kenya and Malawi, but less so in Madagascar where major investments would be needed, or in Nigeria where the return on the investment would be doubtful given population appears to be already well-connected.

<<Figure 4 approximately here >>

2) *Investigating urbanization patterns, land use, and real estate and housing markets*

Examining the effect of accessibility to urban centers on land use, urbanization, real estate prices and housing market dynamics is a research area of great applied interest. This could involve studying how travel times to cities of different sizes influence housing prices, demand for residential properties, and the development of new housing projects. The research might also examine disparities in housing affordability and its impact on socioeconomic inequality. An important research area, facilitated by the *city–region patches* of the MTCR dataset, would be to determine how access to multiple urban tiers based on the travel time to urban centers of different sizes impacts real estate values.

The MTCR dataset can be used to study how the distance from different types of urban centers, as described by similar city–region patches (see Figure 3), affects urban sprawl, agricultural land use changes, and the transition zones between rural and urban areas. Understanding these dynamics can inform sustainable urban planning and conservation policies. It can also assist in the development of housing policies and real estate development projects that address affordability and demand, particularly in regions where access to urban centers significantly influences market dynamics.

A more ambitious research agenda could test the inferred connectivity based on urban form and travel time adopted by MTCR by leveraging large data analysis, such as from mobile phones, to measure realized functional connectivity vis-à-vis potential connectivity of MTCR.⁶ The next step would then be to use agent-based models to investigate the extent to which residential location decisions are driven by the *universal visitation law of human mobility*⁶⁷. In essence, according to this law, the number of visitors to any location decreases as the inverse square of the product of their visiting frequency and travel distance. We could assume individuals have an expectation of how frequently they need services provided by different urban tiers, and their choice of residence is determined by minimizing their overall travel time subject to their available budget for residential expenses. We could expect that using agent-based models that solve the minimization problem described above for all individuals would come close to replicating the population densities in each of the cells in an area. If that were confirmed it would indicate that residential decisions are indeed driven by the universal visitation law subject to the budget constraints people face. This would indicate that the hierarchy of settlements that is observed can be interpreted as a direct reflection of spatial self-organization. On the other hand, deviations could signal that planning and zoning may be playing a major role in shaping residential decisions.

Of more immediate application is research that would enable planners to investigate how access to multi-tier activities influences urban form and land use patterns. Analyzing land use patterns across various city–region tiers (e.g., single-tier, two-tier, three-tier, four-tier) and types (e.g., primary, secondary) at different travel time cutoffs can offer valuable insights for this purpose. This research could inform land use planning and zoning policies that promote efficient use of space, reduce urban sprawl, and encourage compact, mixed-use developments that support vibrant, sustainable urban communities.

3) *Environmental, social and mobility impacts of urban accessibility*

By focusing on how multi-tier city–regions — both their main hubs and smaller centers — are laid out, new research could aim to show how planning decisions impact everything from environmental sustainability to issues of fairness and inclusion. The global MTCR dataset would allow identifying different regional patterns and comparing their characteristics. This research could explore how the structure of multi-tier city–regions, intended as access to urban centers of different sizes, might affect both the environment and the social fabric of communities. It could look at practical questions, such as the carbon footprint of commuting over various

distances and whether people have easy access to cultural activities, parks, and other amenities. Moreover, it allows for comparisons between countries or regions within countries that share similar characteristics in terms of access to different tiers of activities.

The MTCR dataset, by enabling the tagging and analysis of unique patches according to their accessibility profiles and surrounding context, could enable researchers to answer questions more systematically looking across interconnected urban areas and their surrounding regions. For example, patches could be characterized by the types of urban centers they have access to, which could be based on salient characteristics of an urban center, such as whether it is an industrial hub or a service-oriented center. Central questions that could then be investigated in a systematic way through this approach could include, e.g., how the shape and layout of city–regions influence carbon emissions and urban development patterns, how unequal access to green spaces and clean air can reflect deeper environmental injustices, and how limited connections to urban centers can intensify economic disparities across different areas. Ultimately, the findings could guide better policy choices—investments in public transportation, energy-efficient urban design, and ensuring that environmental benefits like parks or clean air are accessible to all in a region. This has implications also for location of environmental amenities in rural areas that could be accessed from multiple centers, meeting demand for such amenities as countries become more urbanized and considering environmental amenities beyond the boundaries of urban centers⁶⁸.

Equally, the spatial organization of city–region patches plays a crucial role in determining access to healthcare, education, and other services, which are vital for social mobility and equity. Researchers can examine how travel times to primary and secondary urban centers impact educational attainment, healthcare access, and economic opportunities. This analysis can reveal barriers to social mobility and inform targeted interventions to reduce inequality.

Such research could contribute to the development of sustainable urban planning strategies that minimize environmental impact, encourage the use of public transportation, and promote the development of compact, energy-efficient urban forms. It could also guide environmental justice initiatives aimed at ensuring equitable access to urban and rural amenities, focusing on improving infrastructure and transportation in underserved areas to bridge the accessibility gap. Furthermore, this research could contribute to the development of educational policies and programs that address disparities in educational access and support social mobility, such as the strategic location of educational institutions, transportation subsidies, and community-based educational initiatives.

4) Economic integration and labor market dynamics and mobility

The degree of economic integration between primary and secondary urban centers within multi-tier city–regions can significantly impact regional economic growth. Accessibility data can be used to examine how the flow of goods, services, and labor between these centers contributes to overall economic performance. Of particular relevance, accessibility to urban centers is crucial for labor market efficiency, affecting job accessibility, commuting times, and ultimately, labor mobility. Analyzing how the spatial arrangement of city–regions influences these factors can provide valuable insights into labor market dynamics. For example, one could examine whether shorter travel times to larger cities correlate with higher employment rates or better job opportunities in adjacent areas, and whether having access to multiple cities with different sizes plays a role in that. Such research could also explore the extent to which accessibility to urban centers affects the types of industries that flourish in surrounding regions.

Novel research could focus on how primary and secondary urban centers and the accessibility between them shape regional economic outcomes. It could examine whether increased connectivity fosters economic integration and growth, how a multi-tier city–region’s structure affects labor market dynamics and worker mobility, and the impact of proximity to urban centers of different sizes on employment rates and broader economic performance. Ultimately, it could highlight the critical role that spatial organization of multiple cities plays in fostering development, creating job opportunities, and promoting overall economic vitality at regional scale.

Insights from this research could inform regional development policies aimed at enhancing connectivity between urban centers, fostering economic integration, and stimulating regional growth through improved transportation infrastructure and economic policies. This type of analysis can also guide labor market policies and urban planning efforts to improve job accessibility, reduce commuting times, and enhance labor mobility, contributing to more vibrant and resilient economies. It could also help shape policies to leverage proximity to urban centers, aiming to boost local economies by attracting businesses and industries that can benefit from such access.

Conclusions

In this Perspective, we have discussed three notable advancements in how researchers can analyze spatial organization of settlements going beyond the standard rural-urban dichotomy: the Degree of Urbanization (DEGURBA) classification, the Urban Rural Catchment Areas (URCA) approach, and the Multi-tier City–Regions (MTCR) approach. Each represents a significant step forward in moving beyond a simple rural–urban dichotomy and providing more nuanced classifications. These innovations signal a fundamental shift in how we conceptualize and govern territorial development. By revealing the importance of peri-urban areas, the relevance of small and intermediate cities, and the hidden architecture of multi-tier connectivity, these approaches challenge the institutional frameworks that still organize policy, funding, and governance around discrete urban-rural boundaries.

The DEGURBA represents a significant methodological advance for researchers seeking to differentiate among urban, peri-urban, and rural spaces based on population size and density. This open-access geospatial dataset has also facilitated the creation of multi-temporal data, further enhancing its utility. It is the more straightforward of the novel geospatial classifications, which facilitates its updating on a regular basis. It is also endorsed by UN Statistical Commission as a globally harmonized approach to delineate cities, towns and suburbs, and rural areas for international statistical comparison.

The Urban Rural Catchment Areas (URCA) dataset adds a critical second dimension: it incorporates travel time to urban centers of varying sizes, which serves as a proxy for the cost of accessing services, goods, and employment opportunities. By incorporating travel time and the size of the largest accessible urban center, URCA provides a more nuanced disaggregation of rural areas. However, the URCA approach links each location to a single urban center of reference, ignoring that a location may have multiple urban centers of reference for different activities. Furthermore, it cannot take into account connections between smaller and larger urban centers.

The MTCR approach offers a distinct perspective for tackling urban issues that individual analyses of urban centers without considering their interconnections might miss. This approach acknowledges the reality that locations, including urban centers, do not exist in isolation. Instead, they are part of a broader network of places that are interconnected economically, socially, physically, and environmentally. By providing a global tessellation

grounded in Central Place Theory, which encodes access to urban centers of different sizes (providing different levels of services and employment opportunities), MTCR provides a starting point for analyses of urban and rural interconnectedness. By using additional spatial layers that provide information on social, economic, and environmental dimensions, deeper insights can be enabled. For example, since a location is associated with a city–region, characteristics of the urban centers that are part of that city region (e.g. infrastructure, universities, etc.) can provide information on the development opportunities of that specific location. On the other hand, the characteristics of the ensemble of rural locations that are part of a city–region can be used to define functional rural areas and inform access to environmental amenities from urban centers. The MTCR perspective supports the development of coherent economic strategies, education systems, and social services that are more effective than fragmented policies designed for urban centers in isolation.

These three approaches each offer unique perspectives and advantages for researchers and practitioners looking to go beyond a simple rural–urban classification. DEGURBA provides a straightforward, yet robust geospatial framework grounded in population density; URCA adds a second dimension by integrating travel time to urban centers; and MTCR emphasizes multifaceted interconnections among places. Different research questions, data requirements, and policy objectives will naturally call for different tools. By accommodating various levels of complexity—from single-city linkages to multi-nodal networks—these global datasets and conceptual frameworks hold great promise for improving our understanding of settlement patterns and driving more inclusive, effective planning strategies worldwide.

Both the DEGURBA highlighting the importance of peri-urban areas and the MTCR framework's revelation that 41-57% of global population can access multiple urban tiers have profound implications for regional governance. Current administrative boundaries and sectoral policies fail to capture these functional realities, leading to misaligned investments and fragmented service delivery. The data suggests new forms of multi-level governance are needed to match the actual spatial organization of human activity—potentially through city–region authorities that span traditional jurisdictions.

The approaches that we compared in this perspective all remain limited by their reliance on potential rather than realized functional ties – classifying grid cells using a mix of population, built-up area, and travel time – they overlook the diverse economic, institutional, and cultural roles cities play. While these morphological approaches provide essential global coverage, the next frontier lies in their integration with functional data to capture actual flows and relationships. The functional approach—whereby a city is understood as a network of socioeconomic relationships—can now be proxied through flows of people and goods measured via mobile phone data and other digital traces. Though data requirements limit such functional analyses to regional rather than global scales, combining morphological and functional approaches would yield a more complete understanding of city–regions that captures both their physical structure and actual use patterns. This hybrid approach would move beyond attempting to derive function from form alone. Furthermore, integrating these datasets with temporal dynamics, as Rozenblat and co-authors⁸ have done for urban system evolution, could reveal how peri-urban transitions unfold over time—particularly when combined with multi-temporal datasets like those now available through DEGURBA. Such integration would illuminate not just what city–regions are, but how they emerge, evolve, and reshape themselves in response to changing economic and social forces.

The progression from DEGURBA's statistical harmonization of urban, peri-urban, and rural areas to MTCR's multi-tier connectivity analysis demonstrates the expanding analytical frontier these frameworks create across scales and disciplines. From revolutionizing basic urban statistics to enabling complex network analyses of territorial development, these approaches provide the empirical foundation for understanding how spatial organization

shapes human opportunity and environmental outcomes. These systematic spatial classifications, which have been the focus of this perspective, establish the foundational architecture that, when integrated with big data analytics, opens unprecedented possibilities for evidence-based regional development strategies in the 21st century.

Author Contributions

AC and SG contributed equally to the drafting of this Perspective. We confirm that both authors have read and approved the manuscript.

Competing Interests

The authors declare no competing interests

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Not applicable

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Figure 1. Schematic representation of classification of population: Panel A for rural-urban dichotomy, Panel B for one-dimensional (DEGURBA), Panel C for two-dimensional (URCA), and Panel D for three-dimensional (MTCR). Note: the size of the spheres are representative of the population in that category.

Panel a: Rural-Urban dichotomy, whereby population is classified as either rural or urban. The size of the spheres resembles the population in a category.

Panel b: presents a stylized one-dimensional urban-rural continuum along the lines of the Degree of Urbanization (DEGURBA), based on population size and density. The classification system consists of three classes – cities of different population sizes, towns and semi-dense areas, and rural areas – and three subclasses for the towns and semi-dense areas as well as three subclasses for rural areas.

Panel c: the Urban Rural Catchment Areas (URCA) adds a second dimension relative to DEGURBA: rural and peri-urban locations are disaggregated into multiple categories, using the shortest travel time to urban centers of various sizes as a proxy for the ease in accessing goods, services and employment opportunities. Each location has one urban center of reference for a given travel time cutoff: A hierarchy of urban centers by population size is used whereby proximity to a larger center dominates over a smaller one in the same travel time category.

Panel d: The multi-tier city–region (MTCR) introduces the concept of locations —rural or urban— potentially accessing multiple urban centers. This is represented by four layers in 3-D with the first one representing the population distribution based on locations' closest urban center, while the other three layers capture the subset of population that has access to two, three, and four urban tiers within a specified travel time (y-axis). For example, the red line in Panel D indicates that there are locations that are in a town (contributing to size of purple sphere), but within 1-2 hours of a small city (grey circle on second plane), and slightly further away (but also within 1-2 hours) from an intermediate city (grey circle on third plane) and 2-3 hours from a large city (grey circle on fourth plane). There are potentially 192 such connections considering four urban tiers and three travel-time cutoffs.

Figure 2. A comparison of spatial representation of the DEGURBA (a, d), URCA (b, e), and MTCR (c, f) data highlights the different level of complexity captured by each.

Panels a-c: Comparison of London and its immediate surroundings starting from the degree of urbanization (Panel a), which has a substantial share of area (i.e. grid cells) around London as low- or very-low density rural areas, whereas in the URCA classification these same areas are classified as being within 1 hour travel to a large city as their main characteristic (Panel b). The MTCR approach strikes a balance because it distinguishes patches based on their closest urban center and any higher tier ones within a given travel time cutoff up to 3 hours (in 1-hour increments). The MTCR approach captures that a location can have access to multiple urban tiers (T1, T2, T3, T4) providing different sets of activities for a given travel time cutoff. (Panel c).

Panels d-f: Comparison is made also at a greater scale —examining a segment of Western Europe that includes Amsterdam, Brussels, London, Paris, and Rotterdam— to see the difference at a more systemic level, including also broader rural areas. For the DEGURBA not much nuance is provided for rural areas: a rural location is classified solely based on its population density, independently of where it is located (Panel d). The URCA dataset

does take these aspects into account, but tends to classify sizeable areas as peri-urban to large cities, even where populations routinely rely on small and intermediate cities, as is the case in Belgium and the Netherlands where most locations are within one hour travel of their urban center of reference (Panel e). The MTCR approach highlights how areas around large cities are not defined solely by their access to those cities.

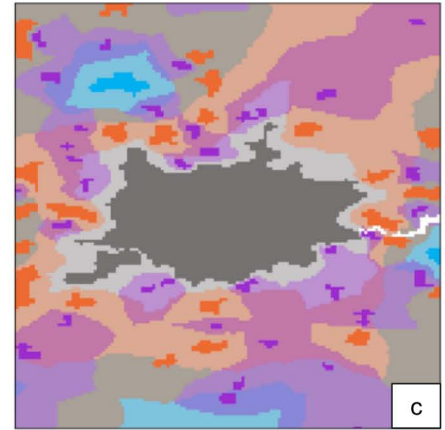
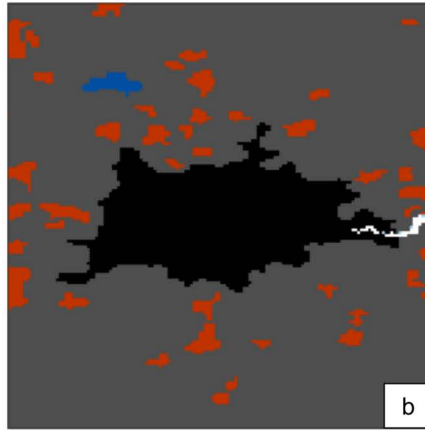
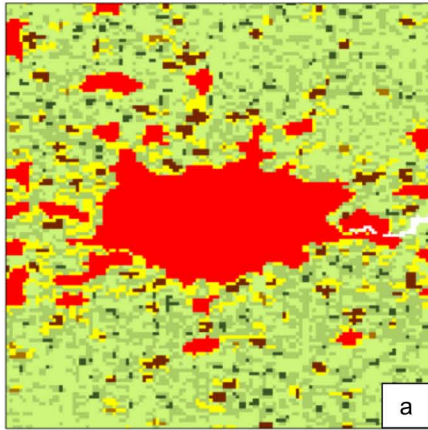
Figure 3. Population distribution across different types of multi-tier city–regions for 1-hour travel time, 2020. Comparison between Kenya, Madagascar, Malawi, and Nigeria indicates different extent of interconnectedness between urban centers as envisioned in Central Place Theory.

The figure presents the share of population living in, or within 1-hour travel time of, the closest urban center, broken down by size of the urban center. Each column sums to 100% and determines the share of the population living in the core or within a 1-hour time range of an urban center, whether a town, small, intermediate, or large city. Row A refers to the share of population living in a rural area with no surrounding urban center, given travel time. Rows B–E apply to locations whereby the closest urban center is a town, small city, intermediate city, or large city, respectively. To illustrate, the population considered within 1-hour travel time also includes those living in the core. The petal diagrams in the grey boxes differentiate the share of population with access to different urban tiers. Percentages in blue refer to the share of population with access to just one urban center within the given travel time. Population values are based on GHS-POP, 2020.

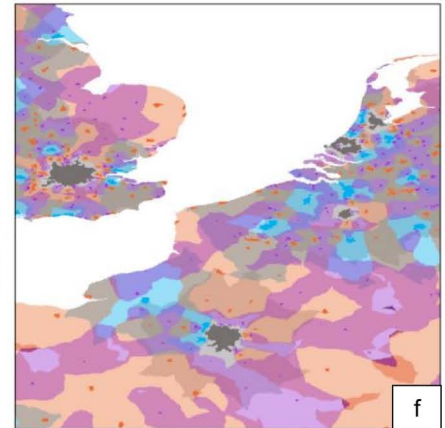
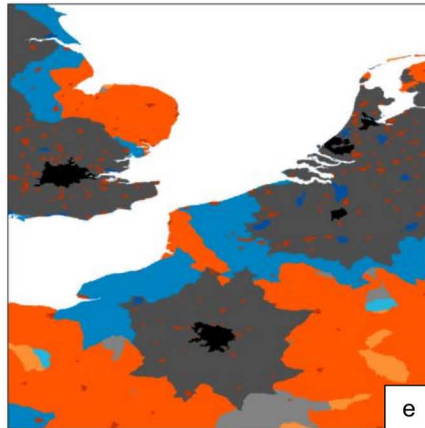
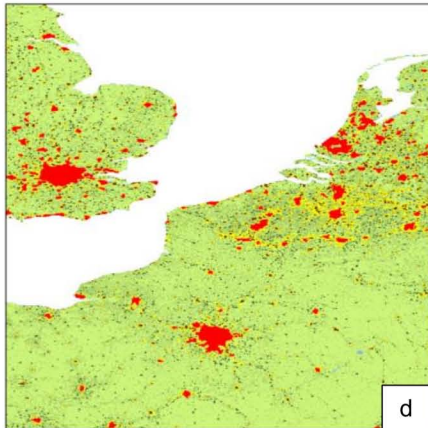
Figure 4. Population transitions in access to higher activity tiers with additional travel time: comparison between Kenya, Madagascar, Malawi, and Nigeria indicates different potential impact of incremental improvements in transport infrastructure.

Figure 4 presents a heat map population matrix that looks at levels of activities reached when transition to higher urban tiers happens as a function of travel time. The axes represent the highest activity tier level (first number) and the travel time cutoff at which it is accessible (second number followed by 'h'). The y-axis represents the pre-transition state in terms of access, the x-axis represents the post-transition state as travel time cutoff is increased. Darker cells indicate a higher share of the population transitioning. For example, the darkest cell in the Kenya heat map expresses a transition from rural locations (0-0h) to having access to a small city within 1-hour travel time (2-1h). The dark color of that cell indicates that over 30% of the Kenyan population is rural but has access to the activities available in a small city (50,000 to 250,000 people) within 1-hour travel time. The diagonal of the matrix represents population that does not transition to a higher tier beyond a given travel time. Madagascar stands out for the high share of population that does not transition out of rural even with three hours travel time (dark cell on the diagonal). Malawi has a large share of the population that is rural but within 1-hour travel time of an intermediate city (0-0h → 3-1h) and that is the highest activity level that can be reached (dark shade on diagonal 3-1h → 3-1h and white cells elsewhere in that row).

London



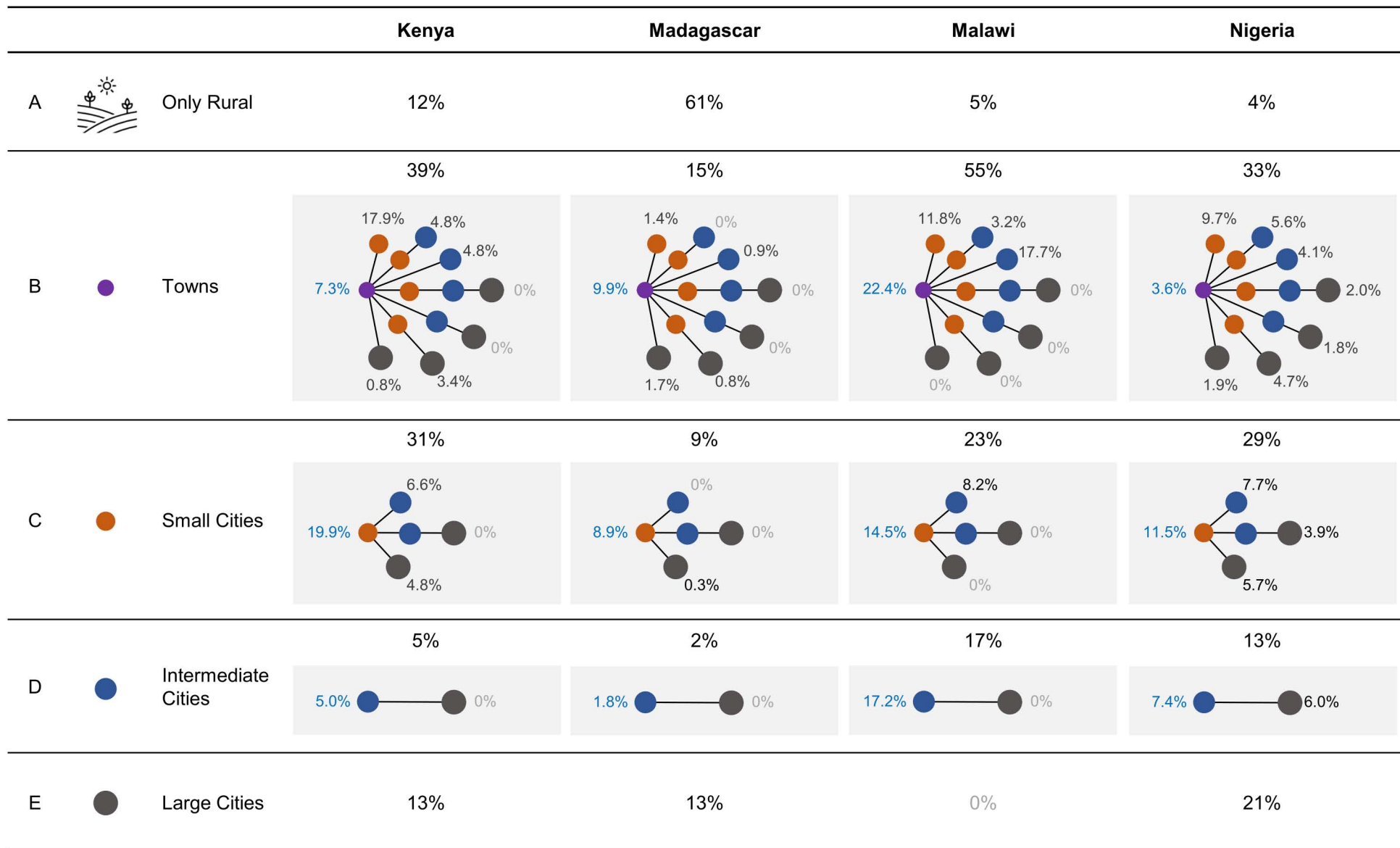
London – Paris – Brussels – Rotterdam – Amsterdam



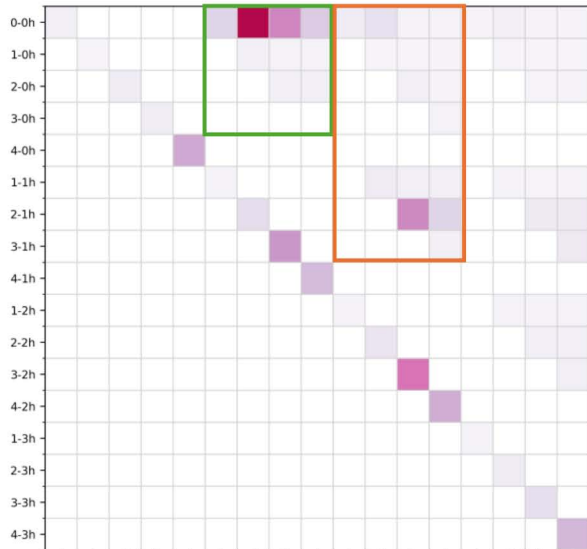
- Water
- Very low density rural
- Low density rural
- Rural
- Suburban or per-urban
- Semi-dense urban
- Dense urban
- Urban centre

- Large city (> 1M)
- Intermediate city (0.25 - 1M)
- Small cities and towns (0.02 - 0.25M)
- < 1 h to large city
- < 1 h to intermediate city
- < 1 h to small city or town
- 1-2 h to large city
- 1-2 h to intermediate city
- 1-2 h to small city or town
- 2-3 h to large city
- 2-3 h to intermediate city
- 2-3 h to small city or town
- Dispersed towns
- Hinterland

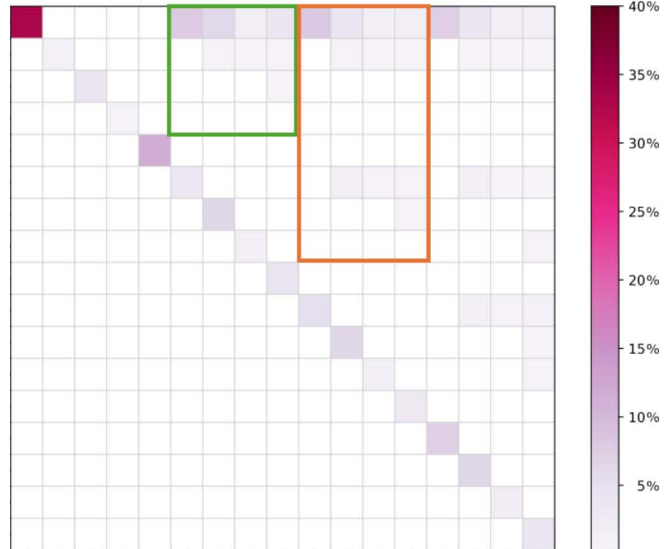
- Town
- Small city
- Intermediate city
- Large city
- < 1 h only T1
- < 1 h T1 & T2
- < 1 h T1, T2, T3
- < 1 h T1, T2, T3, T4
- < 1 h T1, T2, T4
- < 1 h T1, T2, T3, T4
- < 1 h T1 and T3
- < 1 h T1, T3, T4
- < 1 h T1 and T4
- < 1 h only T2
- < 1 h T2 and T3
- < 1 h T2, T3, T4
- < 1 h T2 and T4
- < 1 h only T3
- < 1 h T3 and T4
- < 1 h only T4
- 1-2 h only T1
- 1-2 h T1 & T2
- 1-2 h T1, T2, T3
- 1-2 h T1, T2, T3, T4
- 1-2 h T1, T2, T4
- 1-2 h T1 and T3
- 1-2 h T1, T3, T4
- 1-2 h T1 and T4
- 1-2 h only T2
- 1-2 h T2 and T3
- 1-2 h T2, T3, T4
- 1-2 h T2 and T4
- 1-2 h only T3
- 1-2 h T3 and T4
- 1-2 h only T4
- 2-3 h only T1
- 2-3 h T1 & T2
- 2-3 h T1, T2, T3
- 2-3 h T1, T2, T3, T4
- 2-3 h T1, T2, T4
- 2-3 h T1 and T3
- 2-3 h T1, T3, T4
- 2-3 h T1 and T4
- 2-3 h only T2
- 2-3 h T2 and T3
- 2-3 h T2, T3, T4
- 2-3 h T2 and T4
- 2-3 h only T3
- 2-3 h T3 and T4
- 2-3 h only T4



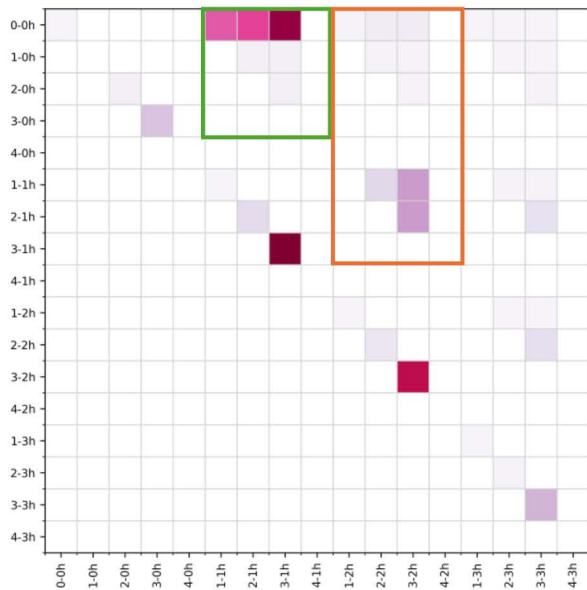
Kenya



Madagascar



Malawi



Nigeria

