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1 Understanding rural-urban transitions in the Global South through Peri-Urban Turbulence

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22 Abstract

23 Much previous research has problematised the use of a binary urban-rural distinction to describe
24 human settlement patterns in and around cities. This paper presents a framework that conceptualises
25 rural-urban transition through the prism of shifts in natural, engineered and institutional
26 infrastructure, in order to explain the processes of rapid change and the dip in service provision often
27 found in peri-urban areas in the Global South. We draw on examples related to the provision of water
28 and sanitation to illustrate the theory and discuss its implications for future research on the peri-
29 urban.

30

31 **Key Words:** Infrastructure, Peri-urban, Rural, Services, Urban expansion, Urbanisation

32

33 Introduction

34 For much of this century, the world's urban population will continue to grow leading to an increasingly
35 urbanised planet¹. A significant consequence of this demographic change is urban expansion, as cities
36 extend outwards incorporating land around them. This expansion of cities is evidenced in high income
37 countries^{1,2}, where urban population growth is modest, but the trend in developing countries in Asia
38 and Africa is especially rapid^{1,3}. This creates ever larger areas of interface between the urban and

39 rural. Depending on the definition, approximately 1 billion people were living in peri-urban areas in
40 2015, with the proportion of peri-urban inhabitants particularly high in low- and middle- income
41 countries⁴. The magnitude of population living in these areas challenges the usefulness of a
42 dichotomous categorisation of urban and rural areas and reaffirms the importance of further
43 theoretical and conceptual development of the peri urban interface⁵⁻⁷.

44 Peri-urban areas are, by nature, complex, multifaceted regions, and so the literature on these areas is
45 spread across numerous disciplines. For example, there is significant scholarship on environmental
46 and ecological conditions⁸ as well as literature on changing patterns of land use⁹. Research has been
47 emerging on 'cityness'¹⁰, 'urban' activities in rural spaces, such as wage employment¹¹, 'rural' activities
48 such as agriculture in urban spaces¹², middle-class colonisation of rural areas¹³, understanding the
49 interdependence between these two realms⁷ and finally the livelihoods and resource management
50 issues at the interface between the urban and the rural^{3,14}.

51 There is therefore a need to bring these disparate themes together in an examination of the peri-
52 urban, what Allen describes as:

53 *"a lumpy rural–urban continuum that challenges conventional distinctions between the*
54 *urban and the rural ... where cities' appropriation and transformation of nature's nutrient*
55 *cycle manifests most intensely."*³

56 Allen³ goes on to argue that peri-urbanisation is a process that sees tensions between the imperatives
57 of economic growth and natural productivity. The result is a zone of intensely heterogeneous activities
58 in space, time and nature that frequently include subsistence and peasant farmers, abattoirs, squatter
59 settlements, reservoirs, factories and mining activities side-by-side. This raises significant questions
60 about the provision of infrastructure and services, about the ability of peri-urban interfaces to provide
61 *"inclusive, safe, resilient and sustainable"* settlement as envisioned in the Sustainable Development
62 Goal 11 on sustainable human settlements¹.

Box 1 – Key definitions for a theory of Peri Urban Turbulence in cities of the Global South, drawing on environmental and urban studies literatures.

- Urban: the territorial area of a city typically characterised by high population density, a significant built infrastructure endowment and municipal governance mechanisms.
- Peri-urban: the territorial area on the edge of an urban settlement typically characterised by rapid growth in population, mixed land use between agriculture, industry and housing and fragmented governance systems. Some densely populated rural areas may display similar characteristics.
- Rural: the territorial area beyond peri urban and urban areas, typically characterised by lower population density, significant agricultural land use and greater prominence of community-based institutions.
- Natural infrastructure: defined as ecosystem services, which are the benefits humans derive from nature (also known as nature’s contributions to people).
- Engineered infrastructure: the endowment of built structures and facilities that enable the provision of infrastructural services, such as water and electricity.
- Proximate institutional infrastructure: the formal and informal institutions that are concentrated within communities, such as community groups or local service providers, which manage public goods and deliver services.
- Distant institutional infrastructure: the formal and informal institutions that are dispersed across communities, such as municipal councils and public utilities, which manage public goods and deliver services.

63

64 Previous conceptualisations of the challenge of sustainable human settlement involve comparisons
65 and contrasts between urban and rural which leads to a partial understanding of lack of services. There
66 are approaches that theorise the urban and rural as areas that are in competition over resources and
67 services¹⁵. For example, Lynch⁵ highlights the relationship between the city and countryside that can
68 be generic – complementary trade in agricultural goods and natural resources such as food, fuelwood
69 and water – in exchange for finance, manufactured goods and services. However, this relationship
70 can also be exploitative, drawing more value from the rural to the city, with limited return trade. A
71 number of studies that indicate that urban demand places pressure on rural woodfuel sources, but
72 that the research suggests that the pressure is mediated by ‘institutional scarcity’^{16,17}. There are also
73 examples of competing economic values applied to peri-urban land – direct use value, indirect use
74 value and non-use value – or the benefits from not using natural resources, such as protection of
75 wildlife, green space for leisure or wildlife conservation¹⁸. In this paper, we focus on the
76 transformations that occur at the frontier of urbanisation and examine how the systems that underpin
77 basic service provision, such as water and sanitation, and enable the management of public goods,
78 like the land or green space, shift during rural-urban transition. We combine literature and theories
79 from urban studies and ecology to form a new framework that explains a peri-urban dip in service
80 provision and process of rapid change we characterise as ‘peri-urban turbulence’ (PUT).

81 The theory of PUT presented in this paper is based on the concept of shifts in the balance and
82 magnitude of natural and engineered infrastructure and local and distant institutional systems during
83 transition primarily in fast growing urban areas of the Global South (Box 1). We characterise natural
84 infrastructure through the prism of ecosystem services – the benefits people derive from nature –
85 especially those associated with regulating services whereby we recognise the role of the environment
86 in purifying water and processing wastes. Engineered infrastructure includes the endowment of built
87 structures and facilities that enable the provision of services, such as reservoirs, pumps, treatment
88 plants and piped distribution networks that can form a water distribution system. The distinction
89 between proximate and distant institutional infrastructure reflects partly the relative scale of
90 institutional systems that underpin basic service provision. Here, we account for the unit of service
91 management between local models of household (self-supply) and community-scale provision against
92 more distant forms of municipal or large-scale market provision. However, it also reflects a distinction
93 between the prominence of more localised institutions in broader areas of rural life, such as
94 community groups, and the more dispersed, impersonal institutional systems that fulfil similar roles
95 in urban life, such as municipal councils. We believe conceptualising the shifts in the balance of
96 natural, engineered and institutional infrastructure can help explain the varied mechanisms through
97 which citizens meet their needs and communities manage public goods across rural, peri-urban and
98 urban areas.

99 Building on this introduction to the constituent parts of the PUT theory, the next section reviews
100 literature on the peri-urban condition and assesses evidence on the reported distribution of
101 engineered, natural and institutional infrastructure across urban, peri-urban and rural areas. It draws
102 on examples from the water and sanitation sector to illustrate similarities and differences across these
103 zones. The PUT theory is then unpacked and explained in more detail before a discussion about its
104 implications on future research on the peri-urban and concluding remarks are provided.

105 **The peri-urban condition**

106 The expansion of peri-urban areas and the growing evidence of their relative neglect highlight their
107 importance in addressing global poverty, however what we know about these areas is obscured by
108 demographic statistics that distinguish between urban and rural populations, thus splitting the peri-
109 urban between these categories¹⁹. Recent work has sought to better characterise the peri-urban
110 condition. One study into child health in East Africa found that it was lowest in the peri-urban interface
111 between the city and rural areas²⁰, whilst a study in South Africa found that around two thirds of urban
112 and rural citizens report that their quality of life had improved over the last five years, but only half of
113 respondents reported such improvement in peri-urban zones²¹. The literature is clear that peri-urban

114 environments can amplify health inequalities^{22–24}. Rapid urbanisation can overwhelm local water
115 supply and sanitation systems and coupled with high-levels of animal ownership this leads to higher
116 infectious disease burdens²². Weiss and McMichael²² argue that these peri-urban dynamics are
117 contributing to a “*major transition in the human-microbe relationship*” that is contributing to an
118 unprecedented era in terms of the emergence and spread of pathogens, from the re-emergence of
119 cholera to new infectious diseases such as SARS (and now COVID-19). In this view, the transitional
120 status of some peri-urban areas represents not only localised welfare issues but also global health
121 security risks. This is further compounded as peri-urban populations are also likely to be exposed to
122 ‘urban’ co-morbidities linked to issues such as air pollution or lower levels of physical activity²³.

123 Assessing the endowment of engineered infrastructure in peri-urban areas is complicated by the
124 structure of most global datasets not using this classification. Those datasets clearly show that urban
125 populations are more likely to have access to infrastructural services, such as water supply and
126 electricity, than rural populations^{25,26}. It is hypothesised that peri-urban areas are likely to sit between
127 the urban and rural levels. However, in interpreting this distribution of infrastructure, it is important
128 to recognise that the welfare costs associated with a lack of access are likely to be higher in peri-urban
129 areas than rural areas. This is because in rural areas ecosystems can fill gaps in infrastructure service
130 provision²⁷ or reduce the risks associated with low levels of infrastructure by absorbing wastes that
131 leak into the environment before they impact human health²⁸. Based on this logic, we would
132 hypothesise that peri-urban populations are often faced with middling access to engineered
133 infrastructure but the highest exposure to risks associated with inadequate access.

134 Similarly, the flow of ecosystem services to inhabitants within peri-urban areas is poorly understood.
135 Provisioning services (e.g. fuel, food, and water; provisioning services) might be most accessible
136 nearby the ecosystems that produce them and in areas where they can be transported easily (e.g. via
137 value chains²⁹), potentially resulting in a dearth in peri-urban areas where local ecosystems are
138 degraded but transport networks are not fully established. Regulating services (e.g. maintaining the
139 quality of air and soil, providing flood control; regulating services), by their very nature, are often not
140 transportable as they prevent, moderate or structure natural processes. As such, regulating services
141 might be best noticed by their absence. In rural areas, healthy ecosystems help maintain habitable
142 environments, but increased pressure from higher population densities can disrupt these processes
143 leading to increased flooding, droughts, soil erosion and disease³⁰. Where established, engineered and
144 institutional infrastructure can mitigate some of the disruption resulting from a loss of regulating
145 services (e.g. paving slopes where vegetation has been lost reduces the probability of landslides).
146 Furthermore, people living in rural areas may have more direct access to cultural ecosystem services
147 (e.g. the ability to develop our mental, physical and spiritual wellbeing; providing space for recreation,

148 spiritual and aesthetic appreciation of nature) than those who live in urban areas as they are often
149 physically closer³¹, although good city planning can preserve access to these services by maintaining
150 urban green space, as well as providing good transport links to natural areas³².

151 Focusing on the differences and similarities in the institutions that underpin the delivery of services
152 and the management of public goods, it is common that the urban and rural categorisation is used as
153 an organising logic for distinguishing between different institutional environments. For example,
154 across much of South Asia, the Panchayat Raj (village council) system of local government reflects a
155 form of direct local government that has historical roots back to precolonial periods³³. In rural areas,
156 large-scale infrastructure development will be overseen by state-level agencies, but many households
157 and communities will manage basic services, such as water supply and sanitation, themselves or via
158 community-based management mechanisms. In this context, service provision is best described as
159 being coproduced between household, community and government³⁴. We conceptualise such
160 arrangements in this paper as proximate institutions, which we formally define as the formal and
161 informal institutions that are concentrated within communities, such as community groups or local
162 service providers, which manage public goods and deliver services in those areas.

163 This compares to urban institutional environments whereby entities such as a municipal corporation
164 take direct control or supervise specialist city-wide institutions such as metropolitan water boards to
165 develop and run infrastructure to deliver services. In such cases, citizens and communities have a
166 much more passive and distant role. These formal urban service delivery systems often exclude many
167 citizens and therefore an ecology of formal and informal private sector providers, such as water
168 tankers and vendors³⁵, also play a role. However, the ultimate 'fallback' option of self-supply is greatly
169 diminished compared to rural areas. In this paper, we conceptualise this environment as reflecting
170 distant institutions, which we define as the formal and informal institutions that are dispersed across
171 neighbourhoods, such as municipal councils and public utilities, which manage public goods and
172 deliver services.

173 In peri-urban areas there is even greater heterogeneity as the rural based models become degraded
174 by growing and dynamic populations, eroding the potential for community-based models, and
175 reducing space for self-supply, yet the urban service delivery models are yet to mature^{36,37}. This
176 process creates a series of poorly recognised institutional tensions in peri-urban regions. For example,
177 in many neighbourhoods long established households will rely on pre-existing infrastructure, either at
178 the household or community level, and can be resistant to shift to new management paradigms that
179 may require paying for services at higher levels than before³⁷. Similarly, there are often governance
180 tensions as rural authorities are hesitant to accept processes of municipalisation that will see local

181 political leaders power subsumed into larger governance units³⁸. In parallel, municipal authorities may
182 often be hesitant to expand their authority to include peri-urban areas whereby the management of
183 public services and goods is challenging³⁸. These institutional dynamics mirror the infrastructure and
184 ecological transition that unfolds within the peri-urban sphere.

185 In summary, the peri-urban is a transitional site whereby the relative capacity of natural infrastructure
186 to support populations is reduced compared to rural areas, yet the endowment of engineered
187 infrastructure is not yet materialised. Communities are often mixed with some residents well
188 embedded in proximate institutional networks, yet community-based management approaches and
189 other similar proximate models become stressed by much higher populations. The expansion of more
190 distant institutional systems, such as those characterised by municipal governance, often lags behind
191 the change in settlement character towards urban-like conditions and can be fragmented across peri-
192 urban regions resulting in a patchwork of institutional forms³.

193 **The Peri-urban Turbulence framework**

194 To help explain why these processes unfold as they do, we propose a theoretical model for rural-urban
195 transitions that argues that changes in natural, engineered infrastructure and distant and proximate
196 institutions represent important markers of rural to urban transition, especially in the Global South.
197 The high-level logic of the PUT framework is derived from four (or more) semi-independent
198 transitions: 1) high levels of natural infrastructure (e.g. ecosystem services) are associated with rural
199 contexts with these being low in urban areas, whilst 2) engineered infrastructure follows the reverse
200 pattern. Similarly, 3) an inverse relationship exists between proximate institutions (high in rural areas
201 and low in urban areas) and 4) distant institutions. In this view, as cities grow nearby settlements
202 experience deep-rooted transitions as their character shifts from 'rural' to 'urban', but this includes
203 an intermediate period of poorly delineated and defined peri-urban existence that can last decades,
204 whilst being characterised by rapid spatial and temporal change and uncertainty. The peri-urban
205 character reflects the instability between the two systems whereby there is higher flux in land use,
206 livelihoods, resource use and services; a transition which we label as PUT (Figure 1), with 'peri-urban
207 turbulence' suggesting a lower level of natural, engineered, proximate institutional and distant
208 institutional infrastructure in peri-urban areas.

209 Figure 1 here

210 **Figure 1** - Levels of infrastructure vary across rural, peri-urban and urban areas. Access to services
211 varies across individuals within each area (arrows) and nature may act as a safety-net in many areas
212 across the Global South (dashed green line).

213 Developing this theory, we draw analogies with but key differences to the red-loop and green-loop
214 theory of rural and urban systems^{39,40}. Red-loop and green-loop theory describes how local natural
215 infrastructure declines during urbanisation, but how engineered, social and institutional infrastructure
216 may fill this gap. In a green-loop system, the overarching pattern is one of direct use of local natural
217 resources⁴⁰. By contrast, in urban areas there is an increased reliance on socioeconomic infrastructure
218 across larger spatial scales (e.g. regional)⁴⁰. A wide variety of evidence supports this theory across a
219 range of ecosystem services, from food production (e.g. subsistence agriculture in rural areas vs
220 transport chains for urban supply⁴¹) to fuel use²⁹. However, there are notable exceptions – e.g. in both
221 rural and urban areas, proximity and access are factors in how much time people spend in green space.
222 Living nearby an urban green space does not necessarily mean people spent time there⁴², as there is
223 a need for some level of connection to nature for people to want to spend time there and gain the
224 associated benefits⁴³.

225 Figure 2 here

226 **Figure 2** Conceptual model of the relationship between the processes of urbanisation and ruralisation.

227 The ‘peri-urban’ character reflects the instability between the two systems whereby there is higher
228 flux in land use, livelihoods, resource use and services. This transition, which we refer to as ‘peri-urban
229 turbulence’, resembles a hysteresis loop and can move in either direction, but with a ‘service gap’ in
230 the peri-urban space between rural and urban dynamic equilibrium states (illustrated in Figure 2).
231 Historically, urbanisation is the dominant trend, but examples of ruralisation also exist⁴⁴. Although for
232 the purpose of PUT we emphasis instability of the peri-urban, we recognise that some may
233 conceptualise rural, peri-urban and urban areas as three related complex adaptive systems that each
234 cycle between phases of stability and change, within the larger system of how humans organise our
235 biosphere.^{5,6}

236 When establishing red-loop/green-loop theory, Cumming et al⁴⁰ suggest a transitional state whereby
237 both local natural infrastructure and distant socioeconomic infrastructure are benefited from
238 simultaneously but distant services predominate as urbanisation progresses. We suggest that this
239 transition is not always perfect, leading to a hiatus between services. As a result, peri-urban areas may
240 not experience the best of both worlds (as might be inferred from red-loop/green-loop theory) but
241 instead go through a temporary void until infrastructure is able to provide access to distant services.
242 In other words, PUT likely results in both reduced local ecosystem services and a dearth of engineered
243 infrastructure that might enable these benefits to be supplemented from distant natural
244 infrastructure. These ‘gaps’ are of high social and political importance when the loss of services results
245 in a large reduction in wellbeing (e.g. sanitation services).

246 We hypothesise that both the rate of ecosystem degradation and the cost of establishing engineered
247 infrastructure are major drivers in determining the dearth of services in peri-urban areas. For example,
248 when the cost of supplying the service is high for the environment, then nature can only support low
249 population densities. Similarly, when the cost of building infrastructure is also high, then it is only
250 economically viable at high population densities. In a situation such as this, the green-loop system is
251 likely to degrade prior to the red-loop system being fully established. For example, in low population
252 densities pit latrines can be used safely, relying on natural processes within the soil to make the waste
253 safe²⁸. However, since establishing sewerage and sewage treatment plants is expensive, it is only
254 viable to develop this infrastructure when economics of scale enable. Thus, medium population
255 densities in peri-urban areas are likely to experience unsafe sanitation – where nature’s services are
256 overwhelmed but engineered alternatives are not yet established. The likelihood of such a gap in
257 infrastructure is increased as the institutional environment is also in a state of flux and therefore is
258 unable to create viable solutions.

259 This type of negative spiral in peri-urban areas is greater for some services than others, and varies
260 across geographic areas. For example, food production predominantly occurs in rural locations, but
261 can continue within urban areas⁴⁵. Even without urban agriculture, food can be transported within
262 cities with relative ease via transport infrastructure⁴⁶ (which are relatively cheap when compared to
263 other forms of engineered infrastructure [e.g. sewerage]). Similarly, an imperfect transition between
264 natural and engineered infrastructure can be avoided through good governance and strong land
265 tenure. For example, some natural infrastructure can be conserved throughout urbanisation through
266 good city planning enforcing protection of green space despite heightened pressure for building
267 developments. As well as this, large scale distant institutions, such as municipal water utilities, can
268 subsidise the provision of services to increase viability at lower population density (e.g. provision of
269 water supply is cross-subsidised from metropolitan areas to small towns and neighbouring rural areas
270 in Uganda⁴⁷). As such, we anticipate PUT to be stronger in areas whereby these forms of cross-
271 subsidies do not exist and the transition in peri-urban areas proceeds unsupported.

272 Although we hypothesise that peri-urban areas have the worst overall turbulence, there are likely to
273 be significant differences between groups living in each context. For example, higher income
274 households and communities living in peri-urban areas will cover the relatively high costs of
275 developing engineered infrastructure and therefore overcome the dearth of services. This manifests
276 most visibly in the phenomena of suburban gated-communities that are now common in major cities
277 of Africa and South Asia⁶. High-income households can also invest in facilities, such as generators,
278 private boreholes and septic tanks to overcome a lack of some services. Low income peri-urban
279 residents will be less able to overcome this lack of engineered infrastructure whilst their options for

280 using natural infrastructure systems is reduced or constrained, as compared to rural citizens. This
281 magnifies inequality as a lack of local natural infrastructure (i.e. as red-loop systems develop⁴⁰)
282 decreases the resilience of households. Particularly, as more vulnerable households are often the most
283 dependent on local natural infrastructure (either directly or indirectly⁴⁰), both for their livelihoods⁴⁸
284 and as a coping strategy for buffering shocks⁴⁹. Thus, the ability to rely on natural infrastructure as a
285 safety net is reduced during urbanisation, potentially resulting in large reductions in wellbeing for
286 those unable to access alternative services, or when these services fail as a result of a shock. For this
287 reason, peri-urban areas face the starkest inequality with citizens that are not well served or
288 integrated into the urban institutional systems or which have access to engineered infrastructure,
289 facing limited alternative options. In this case, they are excluded from the institutional safety nets of
290 the state and nature.

291 **Peri-urban Turbulence as a research agenda**

292 PUT points to the importance of improving our understanding of the peri-urban condition and
293 dynamics. We believe what happens in these settings will determine global society's ability to meet
294 many of the critical challenges of the next decades. As we have argued, under current paradigmatic
295 approaches the necessary expansion of core services such as water and sanitation will be hardest in
296 these regions and the populations living in such environments will be limited in their ability to
297 overcome this gap in provision. This not only represents an issue of immediate human need, but
298 creates a series of broader risks and opportunities. This includes environments in which it is more
299 likely that emerging infectious disease can arise and spread²³ but these settings are also where people
300 are re-setting a pattern of living that will determine their future ecological footprints. Here, we see
301 significant opportunities in viewing the peri-urban as a site for creating more sustainable futures as
302 well as a site for monitoring and responding to local and global risks. Red-loop and green-loop theory
303 emphasised the danger of urban populations having consumption levels so high that they over-exploit
304 distant ecosystems⁴⁰ and we should be wary of responding to PUT by simply accelerating the rate at
305 which populations move towards these types of unsustainable consumption levels, thereby
306 heightening global environmental risks. We believe research is required to understand whether the
307 peri-urban is an opportunity to create more sustainable urban models that allow the meeting of
308 human needs within acceptable ecological boundaries⁵⁰. Some localised and sector-specific efforts on
309 issues such as travel⁵¹ and urban agriculture⁴⁵ may hold some promise yet there needs to be further
310 examination of the peri-urban governance and service delivery challenge to accelerate and scale up
311 such work.

312 We argue that PUT may occur through the interaction of numerous tipping points, resulting in a
313 ‘perfect storm’ of poor infrastructure (e.g. natural, engineered, institutional etc.; Figure 1). The critical
314 thresholds at which each system will tip (e.g. the population density at which household-based on-
315 site sanitation is no longer safe and sewerage or supported faecal sludge management is required²⁸)
316 are notoriously hard to identify but more research can help unlock important insights on when such
317 thresholds might be realised and the multiple pathways to avoid them. Here, we see value in bringing
318 together conventional urban studies literatures^{3,5} with contemporary work on studying systems
319 change from rural perspectives^{34,41,52} and other disciplines^{53–56}. For example, this integration could
320 inform urban and rural planners, designers and architects, to build into their practice wider systemic
321 perspectives that take account of the peri-urban⁵⁷. There is a need to develop pathways based on
322 work such as this to address the services deficiencies in the peri-urban in ways that are sustainable in
323 the long term.

324 The systems change literature provides conceptual frames and methods for studying early warning
325 signals in system change, such as ‘flickering’ and ‘critical slowing down’ that have been used to predict
326 when a system might collapse⁵³. As such, taking the example of sanitation provision, as the critical
327 threshold population density is approached, the on-site sanitation system of latrines might be safe for
328 most of the year but ‘flicker’ to an unsafe state during points of stress such as high precipitation when
329 flooding latrines may cause problems within densifying neighbourhoods. Similarly, the proximity to
330 the tipping point is closer as the ability of the system to recover from these high rainfall periods slows
331 down (i.e. from becoming safe a few days after heavy rainfall, to taking substantially longer). Such
332 patterns have been identified in a wide range a systems, from shifts in freshwater lake systems⁵³ to
333 critical transitions in financial markets⁵⁵.

334 Methodologically, these ‘early warning signals’ are difficult to identify in advance, often being
335 observed only with hindsight – although cutting-edge methods are being developed to address this⁵⁴.
336 Here, we draw analogies between deforestation (reduction in forest areas) and urbanisation
337 (expansion of urban areas). Studies comparatively investigating rural and urban areas are well suited
338 to identify many of the impacts of urbanisation (akin to analyses comparing pristine forests with
339 agricultural fields to understand the impacts of deforestation). However, in order to identify the
340 proximate and underlying drivers of these processes, it is necessary to study the frontier⁵⁸. Ecologists
341 produce high-resolution annual maps of deforestation to track this frontier⁵⁹. Such maps can be used
342 to 1) identify the drivers behind the expansion of the frontier, including down to individual-level
343 motivations⁵² and 2) anticipate the future expansion of the frontier⁶⁰. Applying similar methods to
344 peri-urban areas could lead to a step-change in urbanisation research, e.g. with annual, high-
345 resolution maps of frontiers of urbanisation highlighting key locations for in-depth investigation to

346 follow the process as it occurs. Given the far-reaching consequences for sustainable development,
347 enhancing our understanding of PUT is an important goal for future research.

348 **The way forward**

349 In proposing this framework of PUT as a route for new research, we are aware that any systems-level
350 analysis of rural-urban transition is necessarily abstract and therefore does not account for the varied
351 experiences of individuals living within such systems. There are many rural communities and
352 households that will be 'rich' in infrastructure and linked into distant institutions, whilst urban ones
353 that are comparatively poorer across these markers. However, we believe the meso-level of analysis
354 which we adopt in the framework is still useful as it provides a way of conceptualising rural-urban
355 change in a way that provides an explanatory account for often found deficiencies in peri-urban
356 services and wellbeing. This is a generalisable challenge and this framework provides a robust
357 foundation for building a research agenda that can help address it. We accept that this work is largely
358 conceptual in nature and the next stage will be to validate the framework through comparative
359 datasets and case studies of rural-urban change, but we note evidence presented from the literature
360 throughout this paper that reflect the patterns of outcomes we have discussed and which we believe
361 supports the central tenor of our argument. Moving forward, we believe it is imperative to focus on
362 responding to PUT and to answer questions on when and how authorities can respond to rural-urban
363 transition to ensure the services and public goods are best maintained in a socially and ecologically
364 sustainable way. This may create tensions for urban administrators over their responsibility to provide
365 services for the dwellers in these regions: At what point should they extend their boundaries to
366 incorporate new urban areas? At what point do city authorities include in-migrants? Responding to
367 this dynamic process has implications for a city's ability to meet the needs of its residents and
368 therefore its key performance indicators. Future research in this area should be directed towards
369 supporting such policy challenges and developing pathways to address these concerns. This
370 Perspective develops PUT as an analytical framework to reveal the deficiencies in services experienced
371 by those living in the peri-urban and the implications for both the urban and the rural. There are
372 multiple potential pathways shaped by the specifics of context, rate of change, institutional capacity
373 at various scales and degree of disparity (or sharpness of the boundaries) between the rural and urban,
374 amongst others. The numerous possible combinations of these few variables results in a large number
375 of possible pathways. We believe that system-based approaches for studying rural-urban transition
376 can be used to better anticipate, predict, and explain systemic change thresholds and therefore the
377 basis for pathways to better futures.

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532 **Competing interests**

533 The authors declare no competing interests.

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