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From global 'North–South' to local 'Urban–Rural': A shifting paradigm in climate governance?

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ABSTRACT

As the world takes an unprecedented rural–urban population tilt, the 21st century poses a challenge in further tinkering the internationally evident disparities in access and allocation of carbon. Traditionally, inequalities have been negotiated from economic or 'state of development' perspective. This research, to our knowledge is the first of its kind that plots carbon emission of over 200 nations/territories against a spatial framework. The study argues that existing dualities in the international climate change governance, evident in the so called global 'North–South' economic divide, has a stronger component of 'Urban–Rural' spatial disparity in the making, which is likely to further precipitate into a much local but complex dynamic, particularly relevant to the developing world, that face the double challenge of rapid urbanization and environmental sustainability. The paper discusses the ethical, empirical and governance gaps in climate governance related to the urban–rural carbon dynamics and conclude with a future pathway, committed to procedural justice and sub-nationalization of carbon governance, fairly acknowledging carbon flows at the local level through standard inventories based on consumption criteria. The research offers a shifting paradigm in global climate governance, in view of the inclusion of cities as Goal 11 within the upcoming sustainable development goals and the UNFCCC COP21 to be held in Paris in 2015 and beyond.

1. Introduction

There is a general consensus climate change is proceeding at an unprecedented pace and scale (IPCC, 2013). There is much less consensus on how to solve the climate unbalance in an effective, efficient and fair manner. The main principle settled in the United Nations Framework Convention on Climate Change (UNFCCC) is the "common but differentiated responsibilities" (CBDR) based on the historical and current emissions and the technological and financial capacity to contribute to the solutions. Traditionally, the most visible distinction of the CBDR cuts the globe across the lines of developed countries (or North)

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and the developing countries (or South) collectively termed as the North–South (NS) divide. This has also divided the countries legally (e.g., Annex and Non-Annex 1) and largely the negotiation dynamics (G77+China versus OECD countries). Indeed, there is a greater degree of correlation between cumulative emissions and global warming (Meinshausen et al., 2009; Allen et al., 2009), thereby corroborating the historic responsibilities of developed countries to climate change. On per-capita basis, some proposals like Climate Debt quantify this emission divide between developed and developing countries as 10:1 (UNFCCC, 2009). However, in the last decade or so, the climate science about greenhouse gas stabilization is rapidly advancing and so is the emission contribution from the developing world. A growing consensus is now emerging that any globally stabilization targets cannot be achieved without the participation of developing countries, which today emit about half of global CO_2 emissions and whose future emissions increase faster than the emissions of industrialized countries under "business as usual" (BAU) scenarios (den Elzen and Hohne, 2008). Thus, the initial division between NS to share the responsibility to solve the climate problem is changing.

In addition to the traditional NS distinction, there is an increase in responsibilities in another less explored line of the CBDR: the *urban–rural divide*. More than half of the world's population has become urbanized for the first time in the human history (UNDESA, 2011) with huge implications for climate change, as well as for dividing the responsibilities for the solution. While across the globe, there is an unprecedented demand of fossil-carbon to fuel national economies, it is their urban centers that act as the guzzling engines of energy and carbon. Indeed, urbanization is historically correlated with the massive use of fossil fuel with the industrial revolution. Some accounts are strongly associated with production and consumption of energy within cities indicating that more than 70% of the global greenhouse gases are produced within the urban areas (Stern, 2006) and consume 60–80% of final energy use globally (GEA, 2012). The issue is of a serious concern for urban areas located in the developing world, because as these countries urbanize, the contributions of carbon emissions and greenhouse gases (GHG) from cities starts becoming disproportionately high in comparison to their population share (Satterthwaite, 2009). For example in China, while China attained 50% urbanization in 2011, 40% of the country's CO_2 emissions came from the largest 35 cities, though their population was only 18% of the total (Dhakal, 2009). Moreover, the majority of future population growth for the remainder of this century is reported to occur in urban areas of low- and middle-income nations (UN, 2012). Asia alone added 1 billion urban dwellers in 30 years (1980–2010), more than the population of Western Europe and USA together, and it is expected to add another 1 billion in the next 30 years (ADB, 2012). Africa is expected to urbanize rapidly in the next 20 years adding another 500 million to its cities until 2040 (UN-Habitat, ICLEI, UCLGA, 2014). The International Energy Agency (IEA) expects that 89% of the CO_2 emissions growth in cities between 2006 and 2030 will come from non-OECD countries (IEA, 2008). Hence the growing urban–rural divide poses a formidable challenge to global change and its governance.

The literature on global environmental change has for long highlighted that the present system of environmental governance- *microscopic* or *incrementalist*- is not adequate to address the intensity and spread of global environmental change that the Earth faces today (Young, 1999, 2002; Biermann, 2007; World Bank, 2009). In this research, we examine how the carbon access and allocation (CAA) issues within and beyond the conventional duality of the NS within the existing climate regime has limited our understanding of the global state of affairs and its needed transformations. We argue that the urban–rural disparities are fundamental to shed light on CAA issues concerning climate change, i.e. within the climate governance what is the role of 'urban' and 'rural' as local and sub-national actors and units, from ethical, empirical and governance perspectives. This research argues that *the existing dualities in the international environmental policy, evident in the so called global 'North–South' economic divide, is actually an 'Urban–Rural' spatial disparity in the making. It is likely to further precipitate into a much local but complex dynamic, particularly relevant to the developing world, which faces the double challenge of rapid urbanization and environmental sustainability*.

While this statement is theoretically investigated in Sethi (2015) to formulate a conceptual framework, this paper corroborates it with empirical evidence from international panel dataset for over 200 countries/territories over several decades. The knowledge gaps, conceptual framework, data and research method relevant to this study are presented in Section 2. The results (emerging patterns) are reported in Section 3. This is followed by delving on their implications in Section 4, on issues that influence fair allocation of emissions and its governance at the local level. Section 5 concludes the findings and suggests a way forward.

2. Analyzing the role of global urbanization in climate governance

2.1. Knowledge gaps

Climate governance reveals that there are three major knowledge gaps to improve our institutions and instruments to deal with urbanization and its impact of climate change. First, the *empirical gap* that seeks to scientifically understand the complex transformations at play from diverse perspectives, beyond the obvious norms of economy (GDP) or NS bi-polarity. Second, the *ethical gap* looking into what could be fresh insights from our understanding of ethics and equity to this practical challenge of global change and third, the *governance gap*, in search of appropriate institutions, means and regimes by which we could attain sustainable governance to tackle the climate challenge in a way that is scientifically sound, efficient and socially fair. For more on these intermittent research gaps within the prevailing knowledge domains of three cross-cutting themes, viz: (i) Access and allocation of carbon, (ii) governance and (iii) ethics, fairness and justice refer our theoretical research, Sethi (2015); a short summary of which is presented below:

Empirical gap: Anthropogenic transformation of the earth system creates new forms and degrees of (global) "spatial interdependence" (Biermann, 2007). It is further noted that spatial ecological interdependence binds all nations. This creates a new dependence of states, even the most powerful ones, on the community of all others. This spatial interdependence is a defining characteristic as well as a key challenge of earth system governance that requires an effective institutional framework for global co-operation, more so than most other areas of foreign policy. The interdependence is evident for carbon space in multiple ways: (i) the countries mutually share the carbon space as 'global commons' both to avail and as a sink to sequester; (ii) the wealthy and high emitting people share the global terrestrial space, irrespective of their nationality or NS duality in the sense they exist everywhere (Chakravarty et al., 2009; Kartha et al., 2012). As such, empirical research into spatial (location) basis of emissions is necessary to understand who is the actual divide in the emissions with this fracturing or dissolution of the North–South duality. The need to have a spatial perspective- of the carbon space in the atmosphere and urbanization as demographic, economic, social and environmental transformation on ground could become fundamental to inform the debate on transformation to sustainability.

Ethical gap: It has been thoroughly recognized that allocation mechanisms and criteria are central interrogations for social scientists and decision-makers, considering the fact that North and South dichotomy has taken center stage in the Earth system governance, particularly climate (Gupta, 1997; van Harro et al., 2005). It has been suggested in the literature (Biermann et al., 2012; Prum, 2007, p. 241; Adger et al., 2005) that fairness, equity and justice need to be at the heart of the discussions on global environmental change and the design of a strong regime. They regard new principles devised to ethically address state interests as a pre-requisite to any outcomes in future negotiations on climate change. They seek deeper ethical understanding of the situation which steers ahead of the conventional NS dichotomy, and is inclusive. Yet, it has been acknowledged that research in this field has been scarce in the past, in particular regarding empirical research programmes that could lend substance to the more *policy-oriented*, *philosophical treatises on equity* (Biermann, 2007). It is further emphasized that little systematic analysis has been devoted to studying allocation as independent variable and to analyzing allocation mechanisms in relation to variant effectiveness of the core institutions of earth system governance.

Governance gap: Normative uncertainty requires the development of new norms and conceptual frameworks for global collective action in uncharted territory. Global Earth governance needs a system for allocation of emissions and access to the atmospheric space. It has been argued that more efforts should also be focused on building principles empowering citizens to more effectively push their governments to become greener (Prum, 2007, p. 241). Core questions to be advanced are: "Who are the agents of earth system governance (especially beyond the nation state)? How do different agents exercise agency in earth system governance, and how can we evaluate their relevance?" (Biermann et al., 2009; The Science Plan). In this regard there is a sudden thrust to put local entities at the heart of climate negotiations. Since there are large differences among parties in both developing and developed nations in historical and current consumption patterns, it has been argued that there may be a need for nations to allocate responsibility for GHG emissions among sub-national governments, organizations, and individuals based upon morally relevant principles of justice and equity (Brown et al., ud, p. 23).

2.2. The analytical framework

Debates on global change research are driven by two theoretical and methodological pillars (Biermann, 2007). One is earth system analysis driven by an integrated computer-based approach that brings together models and modules of natural sciences as well as of some social sciences that are able to contribute with models and quantified data, such as economics and some strands of geography. It requires the involvement of most academic disciplines at multiple spatial and temporal scales, research on institutions and governance mechanisms is formally included in most theoretical conceptualizations in this field (Biermann, 2007). Meanwhile, it is well acknowledged that quantifiable hypotheses and computer based modeling are problematic for most students of institutions and governance—and are likely to remain so (Young et al., 2006). The second pillar is the development of an Earth system governance theory, which unites those social sciences that analyze organized human responses to earth system transformation.

Accordingly we devise a two pronged methodology, whereby we study the earth systems dynamics with a rigorous, computer based 'quantifiable' approach and the evolving governance with a thorough 'qualitative' understanding. The 'quantitative' aspect is defined by formulating an analytical framework that evaluates and visualizes the ongoing phenomenon of global change in emissions, urbanization at multiple scales, as elaborated later in this section. Meanwhile, the 'qualitative' study appreciates the empirical and ethical underpinnings in climate governance, along with exploring the implications of the research findings. Climate governance is scrutinized both at international and local levels through semi-structured interviews during February–April 2014 with four experts active in this arena and informed by policy documents, literature published and the internet.

The analytical framework intends to visualize the ongoing phenomenon of global change and the role of different actors in this transformation. It adds another dimension to the conventional thinking in international climate policy, based on economic, NS or geo-political existence, by (a) bringing out the most unrepresented group; LDC in this equation (b) adding spatial dimension to this argument to introduce the local entities in this relationship- urban and rural being the most fundamental spatial, geopolitical and governance units. As the study intends to capture a transforming 'earth systems' state, we introduce an intermediate group representing societies that are urbanizing. In absence of any universal definition by which all nations could be classified as urban or rural, we consider to define it as three equal states of urbanization on a ratio scale of 1 and 100 as $0 < x \leqslant 33$ (low levels of urbanization), $34 \leqslant x \leqslant 67$ (medium) and $x \geqslant 67$ (high levels of urbanization), where

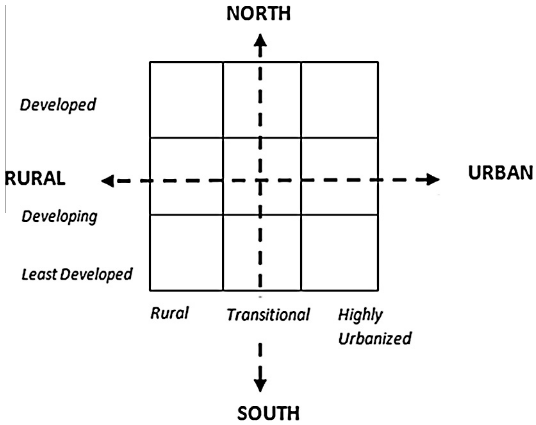

Fig. 1. The analytical framework – 3 × 3 spatial-development matrix.

x is urban population (in percent) for a country/territory for a particular year. Thus, results a 3 × 3 spatial-development matrix, shown in Fig. 1.

2.3. Research method

This investigation intends to explore diverse circumstances of countries, North–South at global level with urban–rural at the local level over the long-term, and how they collectively influence national emissions. Theoretical literature is aplenty in national resource consumption (Catton, 1980; Grimm et al., 2008; Gonzalez, 2005; Satterthwaite, 2011), ecological footprint (Rees, 1992; Wackernagel et al., 2006; York et al., 2003a) and quite recently, carbon/GHG emissions (York et al., 2003b; Satterthwaite, 2008, 2011; Martine, 2009; Dodman, 2009; Dhakal, 2010) as a function of their cities. Scholars have noted that including a control for urbanization rate may improve our understanding, given that urbanization as a phenomenon is conflated with economic modernization. Comparative international studies in energy consumption, emissions or ecological footprints have used specific control variables or their combination, most commonly *population including its* size and growth, *development* or *modernization level* like share of manufacturing, and tertiary sectors, *economic or income levels* like national GDP or GDP/capita and *level of urbanization* (Jones, 1991; Parikh and Shukla, 1995; York et al., 2003a,b; Dhakal, 2004; Satterthwaite, 2009; Jorgenson and Clark, 2010, 2011; Poumanyvong and Kaneko, 2010). Most of the empirical applications have built panel datasets of sample countries to view effects of urbanization on emissions controlling especially for economic development. But it is important to note that none of the above studies has sufficiently reported and visualized the emission disparities between the changing North–South and urban–rural units simultaneously, and their collective implications to influence climate governance. Thus, this research and its findings, is probably the first of its kind that uses a universal set of 209 countries (for which data is available for selected indicators as explained in Table 1) to indicate the effect of different urban–rural levels within changing national circumstances from 1960 to 2010, in a macro-comparative context of their global emission footprint. It involves distributive and mapping techniques while applying certain spatial methods.

In this regard, there is an evolving body of work in spatial distribution of carbon emissions at multiple scales. Different studies use a variety of techniques ranging from a grid-based approach by transposing, distributing or assuming national or global emissions over regional spatial units through complex geographical information software/applications (Dao and van Woerden, 2009; Theloke et al., 2009) to a rather aggregation based method where emissions or energy use or expenditures from various point and mobile based sources are re-classified for an administrative/spatial unit like county (Rue du Can et al.,

Table 1
Synchronization of data from UNDESA, CDIAC data sets from UN and The World bank Database.

	UN Database on country classification and urbanization (UNDESA)	World bank Database on emissions (from CDIAC), gross domestic product (World Bank)	Data for countries excluded in World bank database
More Developed Regions	56	53	Gibraltar, Holy See, Saint Pierre and Miquelon
Developing Regions (excluding LDC)	124	106	Mayotte, Reunion, Western Sahara, Saint Helena, Occupied Palestinian Territory, Anguilla, British Virgin Islands, Guadeloupe, Martinique, Montserrat, Netherlands Antilles, Falkland Islands (Malvinas), French Guiana, Nauru, Cook Islands, Niue, Tokelau, Wallis and Futuna Islands
LDC	49	50	All 49 samples match + 1 (South Sudan)
Total number of countries	229	209	
Additional in WB	Kosovo, Saint Maarten (Dutch part), St. Martin (French part)		

2008; VandeWeghe and Kennedy, 2007; Andrews, 2008). For Sydney, Lenzen et al. (2004) disaggregated total primary energy use in 14 areas, and followed this up with a GHG emissions atlas of Australia at the postal district level (Dey et al., 2007). A pioneering study used the emissions atlas (Vulcan) to compare transportation and building emissions in urban, peri-urban, and rural counties of the United States (Parshall et al., 2010). Due to greater availability of standard global data sets with high confidence and precision, disaggregation of emissions has particularly found application to influence studies capturing role of urban areas and urbanization in climate change discourse (Satterthwaite, 2008; Carney et al., 2009; Sethi and Mohapatra, 2013).

2.4. Data

In this research, we use standard definitions and universally available global datasets on emissions, urbanization, and country classifications to disaggregate emissions of over two hundred country/territories according to their circumstances and rural–urban existence at various temporal points, i.e. six decadal years (1960, 1970, 1980, 1990, 2000, 2010), for details on UN Country classification refer Appendix B. It is important to adopt UN definition of countries, as it appropriately represents national circumstances within the geo-politics of NS, which go beyond the World Bank and similar classifications that entirely rely upon economic indicators. *Urbanization* is defined as the proportion of the mid-year de facto population (in percentage) living in areas classified as urban according to the criteria used by each country or area, obtained from World Population Prospects: The 2011 Revision (UNDESA, 2011). *Carbon dioxide emissions* (metric tons per capita) is defined as annual volume of emissions stemming from the burning of solid, liquid and gas fuels, gas glaring and selected manufacturing processes, including the production of cement, divided by mid-year population and sourced from Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center (CDIAC) data available online at: The World Bank, World Development Indicators Database (http://data.worldbank.org). We do not include biospheric CO_2 (emissions from land use and local sequestration) and other GHG, and aerosols, because they are not strongly correlated with personal expenditures and national carbon intensities (Costa et al., 2011). We understand that rural areas as default tend to act as key sinks generally, the sequestration potential if considered would invariably account for lower carbon emission emanating from rural areas. By applying a spatial analytic lens on national emissions to urban and rural areas, we neglect embedded carbon in exports and imports, a component that is relevant for countries with large shares of trade in their economy. We also do not tackle historical responsibility beyond 1960 due to lack of reliable data on emissions and urbanization for developing countries.

All the datasets were super-imposed in MS Excel 2007, keeping urbanization data of 229 countries/territories from UN as the base. The *least developed countries* (LDC) group was re-classified from developing regions. All three groups – *more developing regions* (MDR), the *less developing regions* (LDR) *minus* LDC and thirdly the LDC – were identified in the database. Data for 20 countries/territories was not available in World Bank dataset (for details of data synchronization refer to Table 1). Hence emissions data of 209 countries/territories was disaggregated using standard *sort* and *filter* operations, for all the three regions (MDR, LDR *minus* LDC and LDC) on the urban–rural gradient, for three categories urban, urbanizing and rural and tabulated for results (refer Appendix A).

2.5. Initial analysis

We start the analysis by responding to what some argue as to whether 'urbanization' qualifies to be an appropriate indicator for CO_2 emission trends. For this, its association with emissions is tested against the usual parameter of economy (with GDP per capita at PPP, 2005 constant international dollars as the indicator) in most of the schemes; using co-relation analysis. Five equation types were tested- linear, polynomial, logarithmic, exponential, power for their Karl Pearson's coefficient in which the polynomial equations coincidently generated the highest values across all type of datasets. For global data of 209 countries/territories, economy demonstrates a positive quadratic association with respect to per-capita emissions ($Y = -0.0003x^2 + 0.0946x$; $R^2 = 0.0889$). For other regions, MDR, LDR minus LDC and the LDC, all show differential results, with LDR *minus* LDC showing the strongest coefficient of co-relation (right hand graphs in Fig. 2).

Meanwhile globally, urbanization has positive polynomial association with per-capita emissions ($Y = 0.0018x^2 - 0.0774x + 2.687$; $R^2 = 0.2258$). All sub-groups i.e. MDR, LDR *minus* LDC and the LDC exhibit positive association with LDC showing the strongest coefficient of co-relation (left hand graphs in Fig. 2). Employing universal data, these findings reinforce contemporary studies on urbanization–emissions that used sampled datasets like Jorgenson and Clark (2010) ($N = 86$ developed countries and LDC from 1960 to 2005) and Poumanyvong and Kaneko (2010) ($N = 99$ countries of all income groups from 1975 to 2005). It supports urban political-economy approaches that indicate that cities being centers of large population and economic activities heavily contribute to burning of fossil fuels and anthropogenic emissions. Although numerically, indicators of economy (GDP/capita) and urbanization, both have limited association with increasing CO_2 emissions, **but it is notable that with all other things being equal, in comparison to GDP, urbanization level of countries worldwide has a greater *R*-square value with CO_2 emissions (i.e. $0.2258 \gg 0.0889$)**. Based on normative and empirical knowledge of associating GDP with country emissions so far, by logic of relative judgment (of higher *R*-square values) makes urbanization a sufficiently qualifying indicator for further experimental investigation. Inequality in the distribution of emissions between developed, developing and LDC countries could reasonably be explained by differences in the levels of their urbanization

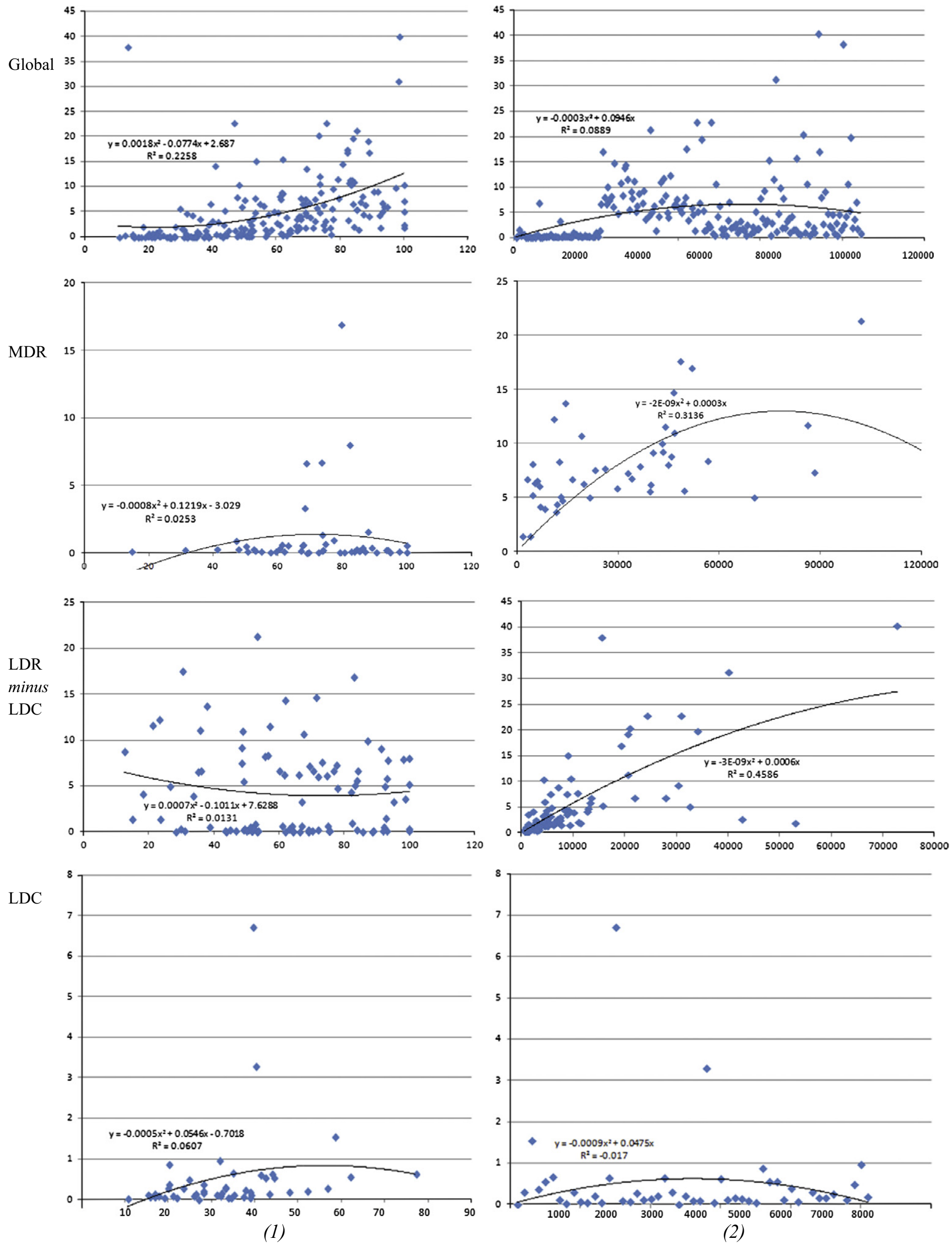

Fig. 2. Comparative results from co-relation analysis shown on left hand side (1) urbanization and carbon dioxide emissions (X = percentage of urban population, Y = carbon dioxide emissions in metric tons/capita); and shown on right hand side (2) state of economy and carbon dioxide emissions (X = with GDP per capita at PPP, 2005 constant international dollars, with Y = carbon dioxide emissions metric tons/capita for 2011) for global data of 209 countries/ territories, MDR, LDR minus LDC, LDC in 2010.

than their economic inequalities (in terms of GDP/capita) as had been the norm. This assessment suggests that globally, state of urbanization of societies is indeed an equally, rather numerically better indicator to analyze their carbon emissions.

3. Discussion of results – unfolding of the phenomenon

The results are generated in the form of two visualizations in Fig. 3 (i) 3D surface and (ii) contour. They could be classified into three broad findings as discussed below:

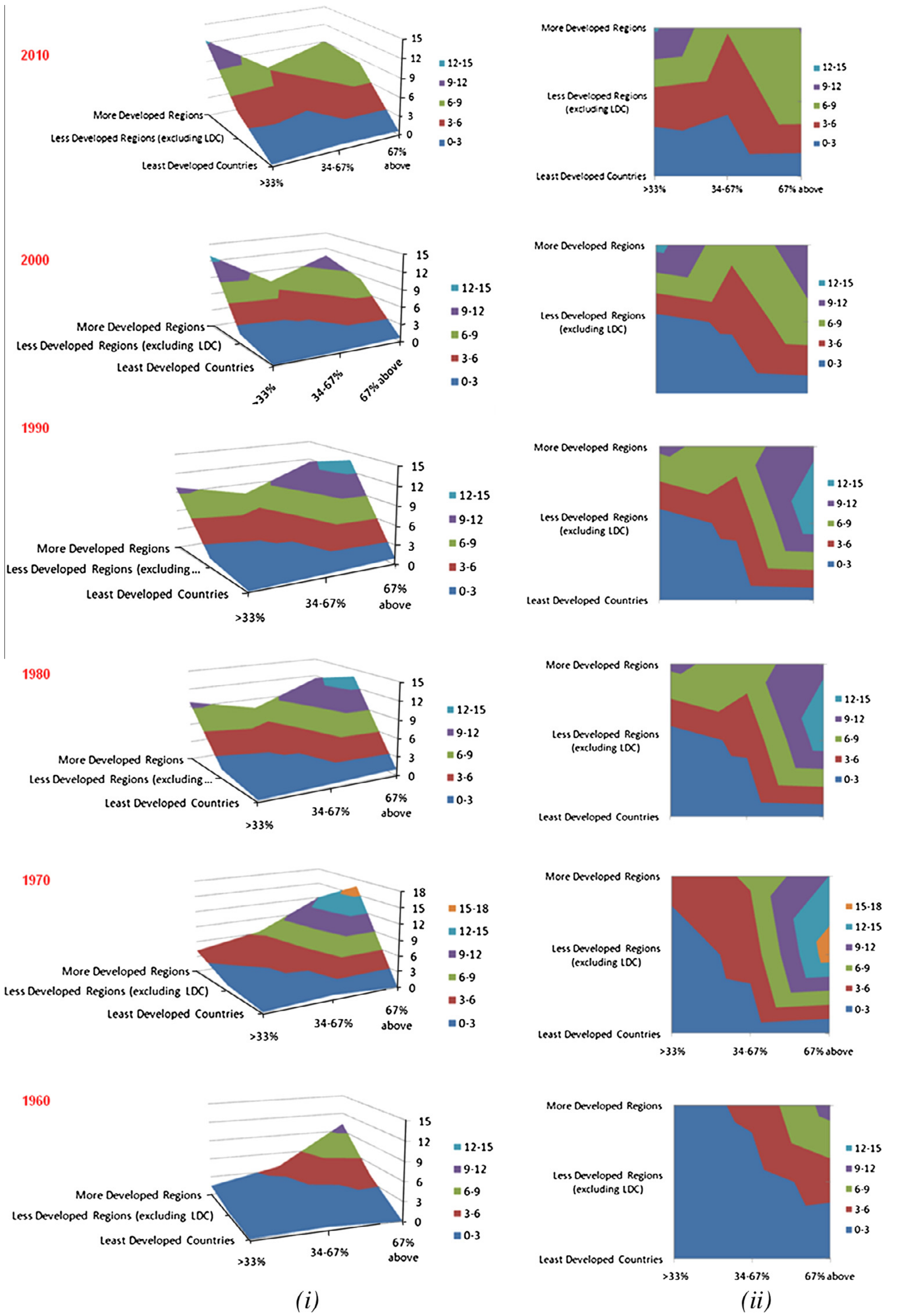

Fig. 3. (i) 3D surface, that shows trends in values across two dimensions (development state and urbanization in this case) and carbon emissions in metric tons/capita as the third dimension forming a continuous three dimensional surface and (ii) contour, that resembles a surface chart that is viewed from above. In both the case, colors represent range of values (carbon dioxide emissions in metric tons per capita). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

3.1. Diluting the NS emission disparity

In 1960, high emissions were concentrated in more developed regions (N – North) with 6.09 t/capita, less developed regions (excluding LDC) had average emissions of 1.47 t/capita, while LDC (S – South) emissions were 0.11 t/capita. In

2010, the emissions for these regions were 8.18, 5.51 and 0.49 t/capita respectively. Although the average NS disparity has since changed numerically from 5.98 to 7.69 t/capita, the NS emission differential has reduced substantially from over 55 to about 17 in 2010. **Difference between the two extremes (i.e. urban North and rural South) has reduced from 10.11 t in 1960 to 8.85 t in 2010, on per-capita basis**. The basic emissions of rural South have slowly grown during this half a century, but the difference with respect to rural North has enlarged manifolds. The differential has increased from 0.1 t to 0.22 t/capita. This reinforces some previous studies on diminishing emission inequalities across the world regions (Padilla and Serrano, 2006) with empirical evidence from spatial attributes. Results also point to the fact that **contrary to the conventional view, categorizing past emissions across strict NS lines could be misleading**. Although, on an average, emissions from developed countries have always exceeded developing regions, there are a lot of exceptions to this general principle, when emissions are differentiated form spatial perspective, in view of the following facts:

(i) *Differentiated emissions from N in 1960–70:* Till the 1960s and even till 1970s, high emissions of the order of 10.21 t/capita in the North were particularly from 14 highly urbanized and prosperous countries, followed by 29 urbanizing countries with an average of 3.23 t/capita while there were still about 9 countries emitting 1.48 t/capita, which were akin to emission in less developing countries, including LDC.

(ii) *Emissions from urbanized LDR exceed urbanizing MDR:* Right from 1960 to 2010, the per-capita emission from highly urbanized societies (above 67% urbanized) of less developing regions have been greater than urbanizing (34–67% urbanized) societies of even the developed countries. Their comparative emissions in tons per-capita are respectively (4.13, 3.73), (16.69, 6.39), (13.84, 7.43), (8.30, 6.90), (9.66, 6.37), (8.30, 6.21) for six decadal points from 1960 to 2010. These findings are in resonance with data from individual cities located within the same region. Dhakal (2004) reported that per capita CO_2 emissions were higher in lower development stage (Beijing and Shanghai) than those at a higher development stage (Tokyo and Seoul). It also supports the *ecological modernization* theory implying that urbanization's impact on energy use and emissions may increase in low- to middle-income countries, but eventually declines in high-income countries, though there are counter arguments as well (Nordstrom and Vaughan, 1999; Rothman, 1998) that suggest that impacts simply shift elsewhere. **Nonetheless, the cross-country data spanning half a century reflects that for higher emissions, your location or spatial circumstances of being in a highly urbanized, urbanizing or rural community could significantly influence your per-capita emissions rather than only national economic or development circumstances, at least while excluding LDC from the argument**.

3.2. UR emission disparity – broadening in rural areas, reducing in urban

In 1960, there were 25 countries with high levels of urbanization (above 67%) with an average emission of 7.17 t/capita, and 74 countries with low levels of urbanization ($x \leqslant 33\%$), with an average emission of 0.28 t/capita. The UR emission differential was 25.60 times. In 2010, countries with high levels of urbanization (above 67%) rose to 74, with an average emission of 8.54 t/capita, meanwhile countries with low levels of urbanization ($x \leqslant 33\%$) reduced to 38, with an average emission of 1.76 t/capita, thus UR emission differential was reduced to 4.85 times. Numerically, this disparity has remained almost constant, 6.89 t (1960) to 6.78 t (2010). **In the past, the highest ever carbon inequalities (15.68 t and 12.40 t/capita) between UR has been recorded for LDR *minus* LDC group for 1970 and 1980 respectively**. Analysis of emissions across all vertical and horizontal positions indicates that UR disparity is thriving and has found enough ground in the North. Within the urbanized societies ($\geqslant$67%), the emission differences across MDR and the LDC have marginally reduced from 10.21 to 8.43 t/capita during 1960–2010. The emissions of urban areas in the MDR and Medium Income (LDR-LDC) are stabilizing in the range of 6–9 t/capita (green color). **This reinstates that irrespective of their geo-political or economic situation, countries with higher levels of urbanization or cities in general are coming together- becoming even in their per-capita carbon throughput**.

Conversely, there is a surprising shift in the MDR's urban–rural emissions as the rural emits more than the urban (contrary to 1960). While there was a reduction in average urban emissions in MDR (−2.3%) from 1960 to 2010, since 1990 the per-capita emissions from rural countries in the North started peaking (from 'blue (gray, 0–3 t/capita)' color in 1960 to 'ocean blue (light gray, 12–15 t/capita)' color in top left corner in 2000 and 2010 in Fig. 3). This is evident from data and estimated emission figures from small countries/territories with rural populations like Liechtenstein, Channel Islands and Faroe Islands. The trend started with their +2.36 t/capita emissions above the urbanized societies in 1990, peaking to +5.22 in 2000, which has relatively stabilized to +3.38 in 2010. The evidence does not seem to conform to either the *urban-environmental transition* theory or the *ecological modernization* theory. Its causation needs further exploration, whether this is due to their geographical situation, "the green revolution" in agriculture (with its intensive use of fossil fuels) or whether it is because the societies are increasingly becoming energy intensive to sustain their rural life-style and economies, such as big cars and houses and heating systems.

The greatest disparity now is, between rural rich and rural poor. On the contrary, in less developing regions and LDC the per-capita emissions in urban societies still exceed rural ones by 3.89 and 0.44 t/capita respectively in 2010. There is an increase in rural emissions of middle income (LDR-LDC), and they are getting even UR (maybe the same trend as MDR i.e. the rural will be following urban). Interestingly, moderately urbanized (33–67%) MDR and LDR-LDC group are similar and less polluting (red color, 3–6 t/capita), averaging at 6.21 and 3.47 t/capita respectively. This *emission-dip* or *decoupling* between urbanization and emissions, associated with moderate levels of urbanization in MDR and LDR-LDC, could perhaps only be better understood through *urban-metabolism* theories applicable to their cities, that would explain optimal impacts owing to scale of economies, agglomerations, associated level of infrastructure, etc. The research suggests that this might be a good balancing figure while planning national urbanization pathways, particularly in developing societies where rapid industrialization and proliferation of urban slums is occurring. In sum, the results underpin that the effects of urbanization on emissions vary across the different stages of spatial (urban–rural) development and refute the assumption of previous studies that urbanization impacts are homogeneous for all countries.

3.3. Other emerging patterns

3.3.1. World-wide stabilization of emissions in the recent past

Over half a century, per capita emissions have grown throughout the world regions (Table 2): MDR (6.1%), LDR minus LDC (30.2%) and LDC (34.8%). But in the recent past, there is a favorable point of departure from the earlier trends. In the last three temporal datasets (1990, 2000, 2010), North has consolidated or plateau its high emissions on an average of 8 t/capita and above. This consolidation is throughout the urbanized, urbanizing and rural spatial units of MDR. Similarly, high emission countries in less developed regions (Qatar 69.22, UAE 65.85, Brunei 63.29, Kuwait 33.37, New Caledonia 22.17, Libya 15.57, Bahamas 15.20 t/capita), incidentally the most urbanized have also stabilized their emissions in the range of 6–40 t/capita by 2010. The only group that reduced their emissions were high urbanized MDR (−2.3%).

3.3.2. Early incidence to higher emission for developing countries

Incidence to moderately higher emissions (in range of 3–6 t/capita) for less developing regions, that are on a pathway to urbanization, physical and socio-economic development is much greater than ever before. In 1960, the occurrence was synonymous with an overall national urbanization of not less than 67%. In the recent decades, it is evident that nations with moderate rates of urbanization (34–67%) could experience similar levels of emissions.

3.3.3. Down South remains carbon poor

All along, LDC continues to have a very low-carbon emission profile, no matter whether the societies are rural or urban. The contour of 3–6 t/capita has still not touched the vast unprivileged populations of LDC residing in Africa and Asia, not even their urbanizing population, which remains largely poor. *The emissions within the LDC are decoupled from spatial location of an individual (urban, rural, etc.) and within the most fundamental level of 0–3 t/capita. This could be attributed to its subsistence state of national economies and income levels.*

4. Implication of the results: Fair allocation and governance of carbon at the local level

We attempt to reconcile the implications of the results within the three identified research gaps: ethical, empirical and governance by expanding our understanding on fair allocation and governance of carbon consumption and its governance at the local level.

Empirical gap: The results validate the importance of spatial parameters like geographical location, scale or degree of urbanization of countries on different urban–rural pathways. As countries develop urbanization rates may be the most significant parameter to explain some differences in per capita emissions, blurring the NS divide for current emissions. For example, China grew economically and urbanized rapidly in the last decades, and have now overcame Europe in per capita emissions of CO_2, even though still much poorer (BBC, 2014). Emissions per capita of cities in China, such as Shanghai, can be much higher than rural China and higher than cities in MDR, such as Tokyo (Lee and van de Meene, 2013). This highlights the importance of dividing national carbon accounting between rural and urban, as well as poor and rich citizens, in order to fully understand the dynamics of the emissions. Moreover, like countries, cities also need to be accountable in their carbon throughput. While the current climate regime (IPCC) follows the production or territorial based approach to account national emissions, there is a growing demand in theory and practice, to estimate emissions (national or city-wide) based on consumption of goods and services or the consumer perspective. If we consider a city which only imports transformed goods, without manufacturing them within the its boundaries, we might observe a paradoxical situation of a high standard of consumption coupled with a very low level of carbon emissions, as results reflect for some developed countries; meaning emissions from production being exported to elsewhere. Similarly, oil-exporting countries though consume less carbon on their territory are held responsible for emissions by importing countries. Accordingly, countries that are gateways to sea-links and airways and benefit economically from carbon exchanges are held least responsible for their emissions. **A more representative and equitable accounting based on consumption of carbon assets or material and energy flows, rooted in principle of 'Ecological Footprint' (Wackernagel and Rees, 1996) is imperative. While national accounts have been prepared on this principle, there is a wanting for such methodology and its application in cities**. This type of accounting would be fairer, ethical and just because it would hold strictly liable the high users and at the same time holds potential to

Table 2
Compound decadal growth rate (in percent) of per-capita metric tons CO_2 emissions during 1960–2010 across countries with various levels of urbanization.

	67% above	34–67%	Less than or equal to 33%	Average
More Developed Regions (MDR)	−2.3%	10.7%	53.1%	6.1%
Less Developed Regions excluding LDC	15.0%	15.8%	62.4%	30.2%
Least Developed Countries (LDC)	NIL	9.6%	17.1%	34.8%

benefit low-users with incentives, as well as identifies spatial emission disparities within countries. However, without adequate rewards, policies and free mechanisms in place, users are unlikely to be aware, sensitive or exhibit consumer behavior of choice and decision making, as in true market conditions.

Ethical gap: With highly urbanized countries of the world emitting carbon dioxide at 8.54 t/capita and the emergence of cities in climate change arena (both as local units of governance and as trans-national members), it could now be reasonably argued to strengthen their role in carbon management and to relocate the responsibility of 'access and allocation' to the local governance level, alike political, legal/functional mandate. **With ample empirical evidence on growing association of urbanization and global emissions in the rich countries and middle income urbanized countries at the cost of rural poor constituencies, it is high time to push the envelope a little further to suggest plentitude of opportunities for the rural subjects in poorer countries to demand their fair share of carbon access and allocation, globally, and also at the country level when it is the case**. Considering their grave technical and financial incapacities, specially against the cities and in fact lack of awareness about their 'carbon right', it may be virtually impossible for them to manage their entitlement separately to begin with, but through national rural forums, coalitions or transnational networks representing rural and poorest world constituencies. There is also a possibility whereby their entitlement amalgamates with the adjoining city/cities, based on their carbon flows and cities become custodians of their hinterlands (city-regions) while managing and negotiating carbon. This would actually help bring the issue of carbon space to ground and relate it with other material and energy flows inherent in its bio-geochemical cycle across local governing units. But is there sufficient consensus toward fair CAA at the sub-national level? This requires to bridge empirical and governance gaps at the local level.

Governance gap: International environmental governance has already been understood as a regime complex (Keohane and Victor, 2010), multiplicity of organizations and polycentricity (Ostrom, 2010), "matching principal" in international law (Adler, 2005). This is in line with 'multilevel' understanding of governance, pressing the need to move away from viewing the state as the primary target of transnational networks (Lipschutz, 1996; Vogler, 2003; Betsill and Bulkeley, 2004). While any treaty would be signed internationally, each country would require internal policies involving participation of government units, business, scientific institutions and citizen group to take mitigation actions. Local-level efforts significantly influence user behavior and choices as shown by Dietz et al. (2009). Using metadata from countries of the developing world (Puppim de Oliveira et al., 2013), it has been further emphasized that it is technically possible to reduce GHG and also achieve urban development goals. **Involvement of multiple agencies in carbon governance at different scales facilitates systematic and transformative governance enabling inclusion, participation in pursuance of climate and development agenda (irrespective of the numerical entitlement), fostering deontological norms of ethics and giving reasonable opportunities to assert politically**. But how would this be governed on ground? Cities are now aptly being perceived as sustainability 'hot-spots' (GEA, 2012) and urban governance of climate change is where international and national carbon control regimes are seen 'coming to ground' (While et al., 2010) for 'governance experiments' (Hoffman, 2011) and reconfiguration of state-based political authority (Bulkeley, 2010), although there is no further detail of what would be the role mechanism and rules of the game.

5. Conclusions and way forward

This research highlights the relevance of taking a more nuanced approach in comparative international research in urban-environment relationships. While internationally, the climate governance recognizes the divide between, or the existence of 'have not' countries, this research helps to differentiate them and establish inequalities evident in carbon emissions owing to their spatial circumstances. It emphatically establishes the diluting of the NS emission disparities, emergence of UR emission disparity, with 'rural' developing countries being the most disadvantaged. While all along in the climate debate, carbon is being negotiated on their per-capita entitlement, they are presently counted nowhere and tend to lose their fair share or actual right to use if they are not awarded at a scale most immediate to them. One of the most important finding is that high or low emissions are also a function of location circumstances, particularly urbanization degree and not merely an outcome of economic or geo-political situations, and hence they could also be decoupled from economic prosperity, as understood generally by traditional theories or assumptions earlier. In this regard, urban metabolism theories could help better understand the nexus between urbanization and GHG emissions at the local UR and national levels. A fair allocation of carbon will have to invariably address and minimize the UR disparities at the local level. There is practical application of this research that contributes to reduce the ethical, empirical and governance gaps – two significant recommendations that would allow scientific evaluation and just management of carbon.

5.1. Sub-nationalize carbon governance – local entitlements with regional trading markets

As the emission disparities move from North–South to rural–urban, there is a need to address the rural–urban inequalities at the different sub-national/local entities at the national level. Although a comprehensive global trading system is unlikely in the near future, a pragmatic way to reduce emissions is to agree on international reduction targets or commitments till a definite year. Subsequently, the decision of reduction mode and carbon governance – self-regulatory or market-based – need to be sovereign for member countries based on their national circumstances and priorities, such as the Intended Nationally Determined Contributions (UNFCCC, 2014). Opening domestic trading market for cities/city-regions and other local actors based on estimated entitlements and monitored carbon emissions will give enough headroom for States to act as independent regulator and penalize heavy polluters within their borders. The devolving of powers to cities and human settlements should not be undermined, considering that their importance has been duly confirmed vide Goal 11 in upcoming sustainable development goals (SDG, 2011). One of the advantages of this system is that, it yields the member countries, who are negotiators in the climate regime today, an opportunity to become regulators and take the learning curve. If the experiment succeeds by 2025, there would be enthusiasm among the member countries to upscale it to a global market. An exception to the above rule could be the LDC that genuinely require handholding, technical support and economic funding from direct payments and later through the international carbon market. Sub-nationalizing emission governance could also bring fresh life to local bodies that generally succumb to political and economic degeneration, owing their allegiance to suzerainty of the State. A practical way to target urban–rural emission equity would be to initiate inventorization in certain countries where data is readily available for consumption parameters.

5.2. Standardize inventories at the local level – based on consumption criteria

We need more spatial accounting of carbon to understand the rural–urban emission dynamics, the objective of a standard carbon or GHG inventory should be to account with reasonable precision the production, consumption of materials, energy in urban and rural constituencies and their mutual flows. An inventory fairly representing carbon flows could facilitate decoupling high quality of life, economic well-being or urban configuration from carbon emissions. Irrespective of one's location or economic background, it would account for wasteful consumption over the equitable norms. This would facilitate users to follow 'less is more' in their actions. The inventory should inherently follow the IPCC's principles of transparency, consistency, comparability, completeness and accuracy. There are some protocols, methodologies and tools in circulation (Carney et al., 2009; Kennedy et al., 2009; Chavez and Ramaswami, 2011; WRI, 2012 being significant ones), but owing to the challenge of data gaps at the local level, they fell significantly short in up scaling. A standard inventory that internalizes carbon emissions with innate processes within the bio-geochemical cycle and human actions in the anthropocene, will do an immense job to the humanity, as it can relate several terrestrial earth system transformations like land use, deforestation, desertification, glacier-melting, and watersheds, that seem to get lost in pre-occupancy of climate change debate. Preparing it on a spatial platform could be an additional asset to locate real-time changes in state and quantities of carbon. A system based on measurement, reporting and verification (MRV) would help track actual use of carbon against the estimated/entitlement. In addition, regular collecting of data and linking it with tradable entitlements at the sub-national level (as discussed above), would lead to a scientific, transparent and participatory carbon governance.

This research ponders that if urbanization and physical development is inevitable, how could we start owning it and transform sustainably with the right governance mechanisms that reflect the empirical, and ethical concerns embedded in climate change debate. Urbanization need not be a process that occurs at the cost of poor and carbon deprived nations and local rural populations. It is evident that there is a need to thoroughly engage with the process of urbanization, development and how effective sub-national carbon governance could be defined. This is a giant leap from prevailing debates and opinions centered around urban governance that largely mandates greater autonomy and devolution of legal, functional and environmental powers to cities, but thoroughly based on the same premise, that now; municipal authorities along with other regional bodies and private actors could have their share of carbon entitlements and mechanisms to use them, trade them or save them for future. The importance of a theoretically inclusive and methodologically rigorous investigation in such inter-disciplinary topic could not be overemphasized. This investigation has a resounding message for a diverse audience. For epistemic and scientific communities, it asserts the need to develop a standard, comprehensive but an easy to use methodology to account sub-national footprints. Also devise transformative strategies toward sustainable lifestyles, city forms and urbanization that are inherently low-emission. For governments, policy makers, administrators, institutions and NGOs in environment and development, it brings a strong message to believe in a system that fosters procedural justice and to sub-nationalize carbon governance. After all, fairness is not a stationery concept, but a scheme that has to be regularly meted out with appropriate governance in place.

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Appendix A

A.1. Summary tabulations

2010

	Urban population (percentage of total population)	Carbon dioxide emissions (metric tons per capita)	URBANIZATION LEVEL - Urban population (percentage of total population) URBAN ⟷ RURAL		
			Most urbanized	Moderately urbanized	Least urbanized
More Developed Regions	75	8.18	9.07	6.21	12.45
Less Developed Regions (excluding LDC	45	5.51	8.3	3.47	4.41
Least Developed Countries	29	0.49	0.64	0.76	0.22

2000

	Urban population (percentage of total population)	Carbon dioxide emissions (metric tons per capita)	URBANIZATION LEVEL - Urban population (percentage of total population) URBAN ⟷ RURAL		
			Most urbanized	Moderately urbanized	Least urbanized
More Developed Regions	75	8.41	9.49	6.37	14.71
Less Developed Regions (excluding LDC	45	5.15	9.66	3.08	2.58
Least Developed Countries	29	0.27	0.56	0.29	0.25

1990

	Urban population (percentage of total population)	Carbon dioxide emissions (metric tons per capita)	URBANIZATION LEVEL - Urban population (percentage of total population) URBAN ⟷ RURAL		
			Most urbanized	Moderately urbanized	Least urbanized
More Developed Regions	75	9.5	10.62	6.9	12.98
Less Developed Regions (excluding LDC	55.6	4.67	8.3	3.51	1.82
Least Developed Countries	29	0.25	0.67	0.35	0.19

1980

	Urban population (percentage of total population)	Carbon dioxide emissions (metric tons per capita)	URBANIZATION LEVEL - Urban population (percentage of total population) URBAN ⟷ RURAL		
			Most urbanized	Moderately urbanized	Least urbanized
More Developed Regions	75	9.9	11.55	7.43	9.8
Less Developed Regions (excluding LDC	51	5.14	13.84	3.73	1.44
Least Developed Countries	29	0.26	0.97	0.55	0.2

1970

	Urban population (percentage of total population)	Carbon dioxide emissions (metric tons per capita)	URBANIZATION LEVEL - Urban population (percentage of total population) URBAN ⟷ RURAL		
			Most urbanized	Moderately urbanized	Least urbanized
More Developed Regions	75	8.98	12.03	6.39	4.2
Less Developed Regions (excluding LDC	45.3	5.12	16.69	4.25	1.01
Least Developed Countries	29	0.23	0	0.87	0.21

1960

	Urban population (percentage of total population)	Carbon dioxide emissions (metric tons per capita)	URBANIZATION LEVEL - Urban population (percentage of total population) URBAN ⟷ RURAL		
			Most urbanized	Moderately urbanized	Least urbanized
More Developed Regions	53.4	6.09	10.21	3.73	1.48
Less Developed Regions (excluding LDC	39.1	1.47	4.13	1.67	0.39
Least Developed Countries	11.7	0.11	0	0.48	0.1

Countries are defined using UN Classification. Urbanization is defined in three equal states on a ratio scale of 1 and 100 as $0 < x \leqslant 33$ (low levels of urbanization), $34 \leqslant x \leqslant 67$ (medium) and $x \geqslant 67$ (high levels of urbanization), where x is urban population (in percent) for a country/territory for a particular year.

Appendix B

B.1. UN classification of countries

A country/territory is classified using the UN nomenclature as followed in the World Population Prospects and several other international studies. Accordingly 'More developed regions' (MDR) or the developed countries, comprise Europe, Northern America, Australia/New Zealand and Japan; 'Less developed regions' (LDR) or the developing countries comprise all regions of Africa, Asia (excluding Japan), Latin America and the Caribbean plus Melanesia, Micronesia and Polynesia. The 'least developed countries' (LDC), as designated so by the United Nations General Assembly in 2010, comprise 49 countries including 33 in Africa, 10 in Asia, 1 in Latin America and the Caribbean and 5 in Oceania. The list of the LDC countries includes: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, the Central African Republic, Chad, Comoros, the Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, the Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, the Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Maldives, Mali, Mauritania, Mozambique, Myanmar, Nepal, Niger, Rwanda, Samoa, Sao Tome and Principe, Senegal, Sierra Leone, the Solomon Islands, Somalia, Sudan, Timor-Leste, Togo, Tuvalu, Uganda, the United Republic of Tanzania, Vanuatu, Yemen and Zambia.

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