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1 Executive summary

1.1.1 A peri-urban / climate risk framework

This review is organized around the Peri-cene conceptual framework (see the outline in Section 2, and **D1-2** for full detail). Conversely, the framework has been developed from this review as it has taken shape.

The review is in four main parts, each with a lead author:

- Spatial dimension of peri-urbanization (lead JR)
- Climate change risk and vulnerability (lead SCR)
- Adaptive governance and its context (lead AK)
- The global peri-cene (planetary peri-urbanism) (lead JR)

Each part contains glossary tables with key citations.

Overview of sources: for peri-urban issues this review builds on the work of the EU project PLUREL (Ravetz et al 2013: Piorr et al 2013), urban foresight studies (REGIO 2011: Ravetz 2015 & 2017), and the global mapping projects GHSL and AUE (Pesaresi et al 2016: Angel et al 2018). For climate risk issues this builds on the work of the EU project RESIN, based on the IPCC WGII (2014), and using the framework analysed by Connelly et al (2018). For adaptive governance there are many sources, starting with Revi et al (2014).

1.1.2 Spatial review

This review is an outline of the spatial dimension of the 'peri-urban'. The peri-urban is a complex many-layered phenomenon, with huge differences around the world (Ravetz et al 2013: Woltjer 2015). It includes features of both urban and rural domains, in an intermediate space where established urban / rural concepts and analytic tools may not apply. There are multiple ways to define the peri-urban: by population density (Piorr et all 2013): by urban proximity: or by socio-economic dynamics of urbanization, or by urban sprawl as the most visible feature of peri-urbanization (Bruegman et al 2007). In parallel the rural dimension is equally important, of social and economic change, leading to new settlement patterns (Simon 2008).

The Spatial Review addresses this complexity / multiplicity in four main parts:

(a) ***spatial layers*** and parameters, (i.e. physical structures and patterns as seen on a spatial map). This also covers spatial hotspots of high value (aerotropolis, business parks, enclaves), and spatial sinks (grey infrastructure, slum settlements etc)

(b) ***functional layers*** and parameters, (i.e. the techno-economic factors and forces which influence or shape the spatial patterns, or influence by cumulative causation).

(c) ***socio-cultural layers*** and parameters. (i.e. all other factors and influences, such as; lifestyles, cultural values, public fiscal issues, technologies and infrastructures. Also, globalization & global dynamics, versus localization of lifestyles, eco-gentrification, 'bypass' effects etc.

(d) ***analysis and modelling the spatial dimensions of the peri-urban:*** i.e. methods and tools for simulation of complex systems in (a) and (b).

Table 1.1: Summary of themes & topics: ***Spatial dimensions***

Spatial dimensions: ('drivers / stressors / exposure')	*Main themes & topics*
Spatial peri-urban types & patterns:	• Urban direct expansion • Urban / rural fringes & gradients • Counter-urbanization effects • Urban agglomeration effects • Hubs, hotspots, sinks, bypasses
Spatial-functional dynamics (factors of growth / restructuring / transition).	• Population growth & housing • Technology & infrastructure • Economy & employment • Real estate & markets
Spatial-social and other dynamics: (STEEP: social, technical, ecological, policy, culture etc)	• Informality & institutions • Social demographics & lifestyle • Environment & resources • Culture & ethics

1.1.3 Climate-environment review

This review looks at the climate-environment field, which is huge and complex: so the review focuses particularly on the peri-urban impacts / interactions / implications of climate change risk. This has to bear in mind some of the above debate on the urban / peri-urban and its complexities, as above. Principle reference points are the IPCC AR5 chapters / reports on urban areas and land-use change, and the Global Adaptation Commission (2019). There are again four main parts to this review:

a) ***Climate change risk***: (hazard & exposure): direct & indirect impacts on the peri-urban, as listed below

b) ***Climate change vulnerability / sensitivity***: peri-urban food-energy-water systems, health, infrastructure,

c) ***Adaptation & adaptive capacity***: here this refers to the physical side (governance etc is covered below), with social or economic driving forces where needed

d) ***Resilience***: can be direct and/or transformational: again here we focus on the physical side of the peri-urban system.

Table 1.2: Summary of themes & topics: climate-environment dimensions

Climate-environment dimensions (causes / hazards):	*Main themes & topics*
Climate change direct effects:	• temperature, • precipitation, storm etc • coastal effects
Climate change direct hazards & impacts:	• wildfire, heatwave, drought, • flood, storm, cyclone • landslide, sea incursion etc,
Indirect hazards & nexus effects	• water resources • farming & forestry • energy & resources • ecosystems & microclimates • critical infrastructure • livelihoods & local economies

1.1.4 Adaptive governance review

The academic scholarship on urban governance and climate change has blossomed over the last two decades. While much of this literature is focused on mitigation, an increasing number of studies have examined adaptation and how it can be realised through innovative modes of collaboration and action. This literature review summarises the most dominant approaches to climate change adaptation as it relates to local and regional governance by drawing on scholarship from urban planning, geography, urban studies, sustainability transitions, political science, and policy studies. The review is not intended to be comprehensive; instead, the aim is to summarise major themes and concepts that have emerged around notions of adaptive governance, multi-level and multi-scalar perspectives, participation and collaboration, and entrepreneurship and experimentation. The scholarship represents contributions from theory and empirical findings in both the Global North and South, and is intended to provide a toolbox for addressing the Peri-cene project objectives.

This review includes 6 main parts:

- ***1*** ***From 'government' to 'governance'***: the emerging agenda for collaborative-adaptive governance, beyond the scope of formal government, planning or regulation
- 2 ***Adaptive climate governance***: including adaptive / collaborative modes of governance :
- ***3*** ***Situated and contextual:*** with a large range of case studies
- 4 ***Participation and collaboration***:
- 5 ***Entrepreneurship, innovation, and experimentation***
- ***6*** ***Cognitive-complexity governance:*** including formal government and spatial planning for the peri-urban, informality and corruption: cognitive dimensions of collaborative governance and a *'collective climate intelligence'*.

Table 1.3: Summary of themes & topics: governance dimensions

Adaptive & cognitive governance	*Main themes & topics*
Formal government, (planning, regulation, fiscal)	• Spatial planning green belt etc • Housing / real estate policy • Infrastructure development • Under-bounding & similar problems
Informal governance: adaptive / collaborative: corruption / informality: community / livelihood	• Informal land-use, settlements • Corruption & nepotism • Social innovation & enterprise
Institutional effects, participation : (networks, coalitions, partnerships)	• Public / Private / Civic / Citizens etc • political economy perspective • political ecology perspective
Cognitive systems transitions, formal vs informal, collective intelligence	• Experimentation & innovation • Social learning & collaboration • Social co-creation & mobilization potential • System transformation potential

1.1.5 The emerging global 'peri-cene'

From the draft reviews, it appears there are overarching issues and challenges to be addressed at the global level, at the edge of the mainstream consensus. This is put here as five propositions, based on emerging literature, for further debate.

- ***Planetary peri-urbanization*** – i.e. the 'peri-cene': this looks at the global level of peri-urban expansion as greater than that of urban areas alone , and showing features of an inter-connected system
- ***Peri-urban transformations***: related to the planetary view, this looks at or beyond the edges of current concepts (e.g. beyond current functional framing of 'urban' as a social and economic metabolism, towards for example, hyper-virtual realities, or hyper-connected lifestyles beyond urban vs rural.
- ***Climatic tipping points***: some recent literature observes arctic melting and similar changes occurring much faster than model predictions. Implications for the peri-urban is that much larger areas may have to relocate or fundamentally restructure, much sooner than previous scenario foresights
- ***Hot-spots, dry & wet-spots:*** the combination of the above produces 'hotspots' (literally), where large areas may become uninhabitable within this century (e.g. temperatures of over 60 degrees in the Gulf states, or the current 'zero cities' without water, or flooding of entire megacities in coastal SE Asia.
- ***Adaptive pathways:*** this makes the link between the above challenges, the societal responses, and practical applications in road-maps and strategic thinking / planning.

2 Peri-cene conceptual framework: outline

*This section is a brief outline of the Peri-cene conceptual framework (see **D1-2** for full detail).*

The literature review is organized around the Peri-cene framework: and conversely the framework has been developed from this review as it has taken shape.

For peri-urban issues the framework builds on the work of the EU project PLUREL (Ravetz et al 2013: Piorr et al 2013), and follow-on urban foresight studies (REGIO 2011: Ravetz 2015 & 2017). For climate risk issues this builds on the work of the EU project RESIN, based on the IPCC (2014), and using the framework analysed by Connelly et al (2018)

2.1.1 The peri-urban-climate challenge

The Peri-cene project has the challenge of working with a multiplicity of causes, effects and responses. Peri-urban development, climate risk and vulnerability, and adaptive governance and pathways, are complex, contingent and often controversial.

To provide a theoretical structure and practical tools for a wide range of knowledge, we have developed the ***Peri-cene Framework***, and its applications through various templates and tools. This provides a practical structure for exploring and mapping, not only tangible problems, but those of 'deeper complexity'.

This combined Peri-cene Framework is a combination of two main 'Models', as in Figure 2.1:

- The '***Causal Model'*** follows a mainly functional frame of cause and effect, in direct problems and responses, between four main factors in the peri-urban climate/environment challenge.
- The ***'Synergistic Model'*** addresses wider systems with deeper complexity and potential for transformation via collective intelligence, with strategic level problems and responses.

Each Model has a role and purpose. The *Causal Model* is a practical place to start to gather data and explore the tangible peri-urban-climate-environment interactions. The *Synergistic Model* is actually more realistic for real-world problems of 'deeper complexity', but more challenging for research and knowledge management, and more suited to a creative process of collaborative (co)-design and dialogue.

The *Causal Model* contains four main themes, or clusters of tangible causes-effects:

- peri-urban development and urban / metropolitan / regional spatial systems
- climate change physical hazards and risks
- climate vulnerability and sensitivity
- governance and adaptive capacity

The *Synergistic Model* then builds on the functional version, in three main dimensions

- ***'Wider'*** communities of stakeholders
- ***'Deeper'*** layers of value and logic, i.e. social, economic, ecological, political, cultural etc.
- '***Further'*** scope of upstream causes and downstream effects

The role of each model is illustrated by a typical example, from peri-urban Manchester, where there is increasing severity of fluvial flooding:

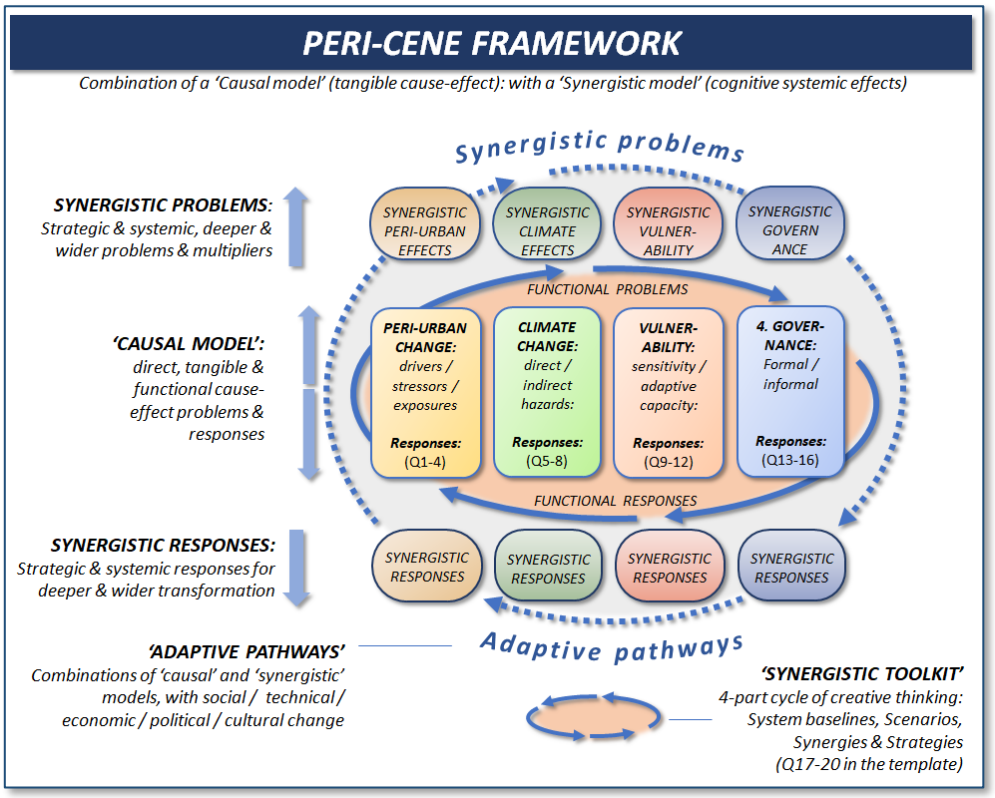
- The ***Causal Model*** would assess the flood levels and risk of return: and then look at how to build up the local flood defences;
- The ***Synergistic model*** would include for indirect / strategic factors in the problem, such as the ownership of land upstream: and then explore the indirect / strategic opportunities for response, such as new forms of land stewardship and governance.

In this way the typical '***adaptive pathways'*** would generally combine responses from both models:

- Direct / tangible / functional responses, such as building flood defences
- Strategic / systemic responses, such as new forms of land stewardship.

Generally such adaptive pathways will emerge through a process of participative dialogue and co-creation with stakeholders. To help guide this, we use the ***Synergistic Toolkit,*** a (pre-existing) four part cycle of analysis and synthesis.

Figure 2.1: Peri-cene Framework



2.2 Peri-cene framework

The full Peri-cene framework is shown in Figure 2.1.

- Firstly, with the direct / tangible *'causal model'* it tracks the basic peri-urban / climate problems, in 4 main themes: then it works out the most practical direct / tangible responses or solutions.
- Secondly, it looks at the deeper, system-wide and strategic problems with the '*synergistic model'*: and explores system-wide and strategic responses, based on an emerging *collective peri-urban intelligence* (i.e. the capacity for collaborative learning, co-creation and co-production).

The combined responses are then put together into ***adaptive pathways***: the key insight and result of the Peri-cene. These adaptive pathways can only emerge through creative dialogue with stakeholders: for this we use a four-part cycle of mapping and design, the *synergistic toolkit*.

The Peri-cene framework can be used for data gathering and analysis, in the form of a (online) template with '20 questions' (details in D1-2).

3 Spatial review: the urban edge and beyond

Structure of the spatial review:

This section includes three inter-connected 'layers' of spatial system, followed by a fourth theme on spatial analysis and modelling:

a) ***Spatial layers*** include: population density, urban contiguity, sprawl, and spatial proximity:
b) ***Functional layers*** include: techno-economic factors such as labour markets / commuting, economic integration, globalizing effects;
c) ***Socio-cultural layers*** include: place-based identities, social systems, attitudes and perceptions.
d) ***Spatial analysis & modelling:*** i.e. methods and tools for analysis and simulation of spatially explicit systems in (a) and (b). (social-cultural issues being outside the scope of technical modelling).

The peri-urban zone may become the most common type of settlement pattern in the world in the 21st century. In wealthy areas it is characterised by affluence and conspicuous consumption: in lower income areas, poverty and social displacement are more common, where the peri-urban is a front line between the problems of the city and the rural areas. Underlying this is the changing nature of the city itself: as well as the physical expansion of urban or suburban built environments, there are wider economic, social and cultural dynamics of change in peri-urban areas that are neither urban nor rural in characterisation. Therefore, we need to look beyond the conventional divide between 'urban' and 'rural', to a new kind of territory where the 'peri-urban' is the central feature. However this is rarely a static area on the map, rather in continuous flux and transition. There are spatial transitions or gradients between urban and rural areas. There are also time-based transitions between (generally) local resource-based economies and globalized-metropolitan economies. The peri-urban in that sense acts as a litmus test of change and transition, not just locally at the urban-rural interface, but in the shape of the wider city-region, (also termed the 'rural-urban-region') (Ravetz et al 2013). As the conceptual scope of the 'urban' then expands to a global scale 'planetary urbanization', so might the peri-urban and/or peri-rural, as a 'planetary peri-urbanization' (Keil 2018: Brenner 2015).

3.1 Spatial layers

The peri-urban is something between, neither urban nor rural. The historical dichotomy of urban and rural space started to blur in Europe with the formation of nation states, industrialisation and the liberalisation of the economy in the 19th century (Bengs & Schmidt-Thomé 2006). However, firstly with the introduction of mass commuter transport systems, and then with the spread of car

ownership, the countryside close to towns became a potential place for living, recreation and sometimes working for urbanites. This development led to an expansion of cities not only in physical terms with low density housing but also in terms of functional relationships, creating an area of urban influence around cities, also called the urban field (Friedmann & Miller 1965).

3.1.1 An urban-rural continuum?

The blurring of the urban-rural boundary inspired research into the idea of an urban-rural continuum. Bryant et al (1982) illustrated this by a model where the urban-rural region ranges from core city through inner and outer fringe, a zone of an urban shadow and out to the rural hinterland. More recently the term *'urban-rural interface'* was discussed, emphasizing the mixed character of these areas without fixing them on a single, simple gradient (Simon 2008).

There are many angles on this complex phenomenon. 'Ex-urbanisation' was originally coined as "ex-urban" by Spectorsky (1955), who described the development of a ring of wealthy rural communities around New York City, characterized by settlements of urban professionals commuting to the urban core for work. Today many of these areas could also be called suburban, and Nelson & Sanchez (1999, 689) argued that ex-urbanisation does not differ from suburbanisation, but that ex-urbia "is simply the latest incarnation of the continued suburbanisation of American cities." Ex-urbs are nowadays found in a different manifestation in places such as southern Spain, where they form specially built estates for retired people from northern Europe (Zasada et al., 2010: Taylor & Hurley 2016)

3.1.2 Counter-urbanization?

In contrast "counter-urbanisation" implies an opposite trend to simple urbanisation, i.e. an increase in migration from the city to the countryside (Robinson 1990). Besides the relocation of services and industry into rural areas, the development of part-time farming, second homes and retirement migration play an important role in this process. Champion et al. (1989) emphasized that it is not a unidirectional movement but a complexity of flows tending towards de-concentration.

These various concepts and definitions are summarized in Table 1.

Table 3.1: |Spatial layers of the peri-urban: summary of concepts & sources

PERI-URBAN CONCEPT	*Example definitions*	*Citations*
'PERI-URBAN ZONE' *(*Residential density concept:	Discontinuous built development, containing settlements of less than 20,000, with an average density of at least 40 persons per km2 (averaged over 1km2 cells)	Piorr et al, 2011 Ravetz et al 2013
'RURAL-URBAN FRINGE' : Spatial gradient / interface concept:	' [...] that zone of transition which begins with the edge of the fully built-up urban area and becomes progressively more rural whilst remaining a clear mix of urban and rural land uses and influences before giving away to the wider countryside'.	Countryside Agency (2002; cited in Gallent and Andersson 2007)
'URBAN SPRAWL' : as a system concept:	'unplanned incremental urban development, characterised by a low density mix of land uses on the urban fringe': 'Low density, scattered urban development, without systematic large scale or regional public land-use planning':	EEA 2006: Reckien and Karecha 2007: Galster et al. 2001
'URBAN SPRAWL' : as a spatial definition	'low values in one or more of eight measures: density, continuity, concentration, clustering, centrality, nuclearity, mix of uses, and proximity	Bruegmann 2008, p. 18;

3.1.3 Peri-urban as land-use and density?

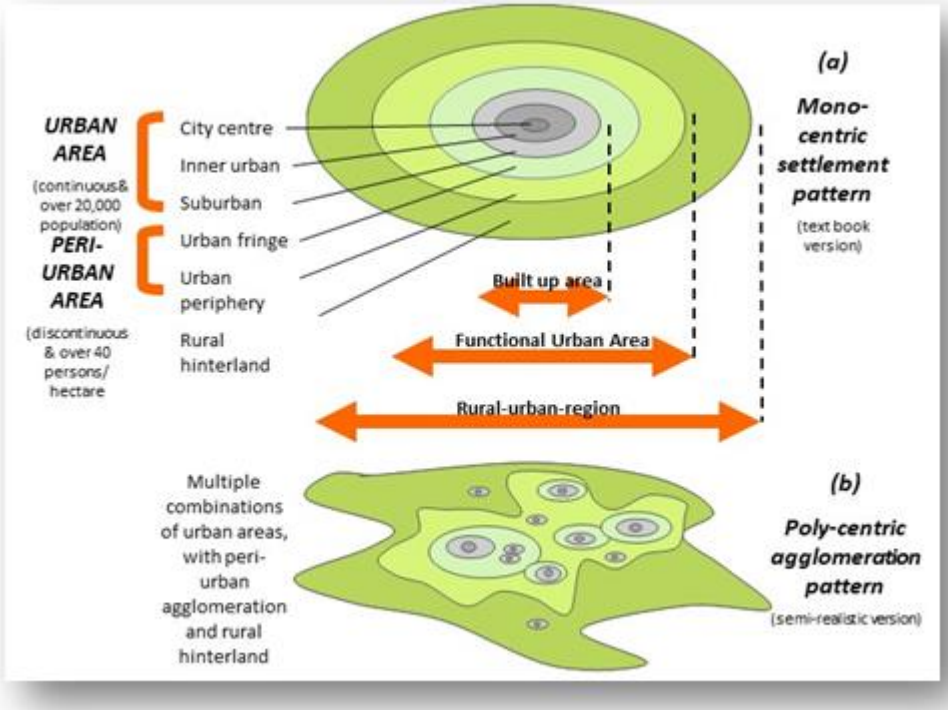
A low-medium residential population density is often taken as the primary definition of the peri-urban, as an intermediate zone between urban and rural. However, much depends on the unit size for analysis, and the questions of contiguity and proximity to urban centres: with further complexity on transient populations or non-residential uses, such as airports.

The PLUREL (the large EU-funded project on 'peri-urban land-use relations') considered the peri-urban to be part of a 'rural-urban-region' (RUR) as unit of analysis (Piorr et al 2011). The RUR contains a range of area types discerned from a wide literature review (e.g. Bryant 1982: Champion, 1999: Loibl & Toetzer, 2003, Gallent et al. 2006: Leontidou & Couch, 2007). The basic spatial types which define the RUR include, as shown in Figure 1:

- Urban core: including the Central Business District and the site of many other civic and cultural functions and some public spaces associated with these;
- Inner urban area: generally higher density built development (built-up areas) including residential, commercial and industrial types of uses and some public open and green space;
- Suburban area: generally lower density contiguous built-up areas, which are attached to inner urban areas, and where houses are typically not more than 200 metres apart, with local shops and services, parks and gardens;
- Urban fringe: a zone along the edges of the built-up area, which comprises a scattered pattern of lower density settlement areas, urban concentrations around transport hubs, together with large green open spaces, such as urban woodlands, farmland, golf courses and nature reserves;

- Urban periphery: a zone surrounding the main built up areas, with a lower population density, but belonging to the Functional Urban Area, as below: this can include smaller settlements, industrial areas and other urban land-uses within a pattern of functional agriculture
- Rural hinterland: rural areas surrounding the peri-urban area, but within the rural-urban-region and accessible within a commuting time and so their rural character is affected by residents with urban incomes and lifestyles.

Figure 3.1: PLUREL concept of peri-urban areas and rural-urban-region



The **peri-urban area** therefore includes both the urban fringe and urban periphery segments of the above description. This enabled a working definition of the peri-urban, suitable for the European context (Ravetz et al 2013):

> ***'discontinuous built development, containing settlements of each less than 20,000 people, with an average density of at least 40 persons per km² (averaged over 1km cells)'.***

Figure 1.1 shows two interpretations of this definition. The upper picture shows a simple text-book version of a mono-centric settlement pattern, surrounded by nested circles as a Functional Urban Area (FUA). A more complex and realistic version below shows a poly-centric agglomeration of settlements with different sizes and patterns, surrounded by a fuzzy peri-rural hinterland. In the poly-centric version, the peri-urban areas are not only surrounding the urban, they become a distinct

geographical type and territory of their own, often amorphous and fast changing. FUAs may then overlap and merge to form urban or city-region agglomerations, existing settlements change their shape and function, and in larger FUAs there are many areas with a complex mix of infrastructure, housing, industry, open space, and undefined land in various stages of disuse or re-use – a challenge for any kind of definition.

3.1.4 Urban sprawl?

Perhaps the most important definition is that of **urban sprawl** – generally seen as a land use pattern with lower density, inefficient or wasted land-use, car dependency and dislocation from local markets and services (Reckien and Karecha 2007). This raises many questions on which spatial scale or spatial unit of analysis is to be assessed: for example, is an airport or industrial complex outside the main urban boundary to be defined as urban sprawl, or as economic development, or both?

A more technical definition of sprawl looks for low values in one or more of eight measures: density, continuity, concentration, clustering, centrality, nuclearity, mix of uses, and proximity (Galster et al 2001). In simple terms we use two definitions for sprawl – *'unplanned incremental urban development, characterised by a low density mix of land uses on the urban fringe'* (EEA, 2006): and also: *'Low density, scattered urban development, without systematic large scale or regional public land-use planning'*. (Bruegmann, 2008, p18: Reckien and Karecha, 2007). Such definitions can be explored further by looking at the systems qualities of sprawl versus normal urban systems.

At the system level, a city or city-region can be framed as a 'system' of inter-connected parts, with multiple layers of interactions, social, economic, technical or political. By contrast areas of urban sprawl are 'non-systems' characterized by gaps and conflicts, where nothing makes sense, where the concept of 'system' is hardly relevant or useful. This perspective then helps to design policy responses or 'sprawl repair', often in situations of governance gaps, economic exploitation, bypassing of local livelihoods, destruction of local ecosystems, and so on (Tachieva 2009).

3.1.5 Global urban expansion?

The global urban system shows huge variety, as illustrated in the 'framework' in section 2. In one 2005 World Bank study, cities in developing countries were found to have three times the population density of cities in industrialised countries (Angel et al, 2005). However, the current trend is for density to reduce by 1.7 per cent per year; so if this trend continues to 2030, the built-up area of these cities will triple to more than 600,000 km^2, while their population doubles. A global remote monitoring study looked at four main types of urban growth: low-growth cities with modest rates of infilling; high-growth cities with rapid, fragmented development; expansive-growth cities with extensive dispersion at low population densities (generally North American); and 'frantic-growth' cities with very high land conversion rates and population densities (generally found in developing countries) (Schneider and Woodcock 2008). Each of these types had different spatial patterns, whether dispersed or constrained: and scattered or contiguous development. To this could be added a fifth type, that of negative growth, or shrinking cities (Sinn et al 2013). Generally, these definitions

of 'urban' include what we term here the 'inner peri-urban' or urban fringe, in close proximity or within the shadow of the fully urbanized area. The 'outer peri-urban' – (which could be termed 'peri-rural'), where the rural areas are in transition under urban pressures – has not yet been studied at this scale.

Generally the process of urban expansion should be seen not only as a negative change, but also one with positive benefits for the majority of the world's population, who occupy on average a space of 3.5 m^2 per person (Hardoy et al 2001: UN Habitat 2012). However, the implication is that cities in both developed and developing countries should be making strategic plans for large scale physical expansion, building capacity for governance, investing in sustainable infrastructure, and managing climate risk with forward looking adaptation.

3.2 Functional layers & dynamics of the peri-urban

3.2.1 A wider functional region?

It seems clear that peri-urban area types are not isolated entities, but highly inter-connected parts of a larger 'urban system'. There are different concepts in use of urban systems with different boundary definitions – some of them flexible, some specific. The 'city-region' is a much-used and flexible concept of a city within its spatial-functional hinterland, with overlapping economic, ecological, social or political units (Ravetz 2000). The PLUREL project focussed on two main levels of spatial-functional system organization:

- **Functional urban area: (FUA)**: "an urban core and the area around it that is economically integrated with the centre, e.g. the local labour market. Belonging to a commuter catchment area, FUAs represent common local labour and housing markets" (Nordregio et al. 2005). This overlaps with the statistical unit of the 'Larger Urban Zone', as used in the European Urban Audit (ESPON 2008).
- **Rural-urban-region (RUR)**: "spatial clusters of three interrelated regional sub-systems – the urban core, the peri-urban surroundings and the rural hinterland…. areas of recreational use, food supply and nature conservation located in predominantly rural areas are also part of the rural-urban-region." (Piorr et al 2011).

Peri-urbanisation also includes other functional effects and interactions, not included in population migration and change. These include movements for commuting or recreation, a growth in part time or hobby farming, new growth zones around airports or campuses or malls, or other effects of the integration of rural areas in the system of a FUA. This means that the peri-urban can potentially be described based on (economic) functions, such as the linkages with local labour markets and commuter catchment areas (Nordregio et al. 2005).

3.2.2 Peri-urban interfaces and transitions

Often, the peri-urban is used to describe newly urbanised zones at the fringes of cities, especially in developing countries, which are then called the 'peri-urban interface' (Adell 1999; McGregor, Simon,

& Thompson 2006). From a European perspective, peri-urban areas are often understood to be mixed areas under an urban influence but with a rural morphology (Caruso 2001). The Council of Europe (CEMAT 2007) defines the peri-urban as a transition area moving from strictly rural to completely urban, related to a high pressure towards urban development (Bertrand 2007). Conversely, peri-urban areas can be far from ephemeral, but instead can form a new kind of permanent landscape. Furthermore, the development is not necessarily limited to purely physical development with urban characteristics, but often marked by the emergence of urban activities in rural areas like hobby farms and second homes (Briquel & Collicard 2005; Caruso 2001). The fact that the residents can be considered urbanised even if they do not live in a strictly urban spatial type, because of their lifestyles and social focus on the urban, for example, emphasise the uniqueness of the zone.

3.2.3 Transport as enabler

Planners and engineers have conventionally supplied to the growing demand for roads and parking, while dismantling transit systems: for instance in the UK auto-engineering of reached its physical limits only after many inner cities and towns had been turned inside-out by road schemes (Tetlow & Goss 1965). Meanwhile the outer cities began to self-organize, first around mass transit, and then around the automobile and the highway, in reinforcing feedback of car-dependency (Newman and Kenworthy 1999). One result is social isolation, where residents overlooking a fast highway tend to have less interaction compared to those on a quiet residential street (Rapoport 1977): more generally there is a trend towards a landscape of 'non-places', transient, artificial, anonymous and alienated (Auge, 1999). Such a logic of speed also generates 'auto-areo-mobility', mono-functional nodes with rapid expansion at road interchanges, where the main pedestrian areas are now in hyper-malls and airport terminals (Kasarda & Lindsay 2006).

Charting transport energy demand against urban density shows a huge spectrum, from hyper-dense Hong Kong at 300pph (persons per hectare), to Atlanta or Phoenix, with just 6pph (Newman & Kenworthy 1999). On this measure there are long running questions on urban density, accessibility, energy / carbon, and the ideal shape of a (so-called) sustainable city (Breheny and Rookwood 1993). One practical application is the scheme of 'Urban Fabrics', which maps three types of urban form and accessibility (Newman et al 2016):

a) 'Walking city': population densities of over 100pph (persons per hectare): generally up to 2km radius from the city centre or main transit hub.
b) 'Transit city': densities in the region of 50pph, and a typical 8km radius from the city centre.
c) 'Automobile city': densities of less than 20 pph, more often spread out across large areas.

On a similar basis, countless policies and plans aim to promote walking / transit cities, dense liveable spaces with mixed uses, there are powerful forces pushing in the opposite direction towards an 'automobile city', with peri-urban densities and spatial patterns. European cities of generally slow or zero population growth, even with sophisticated urban planning systems, on average have peri-urban areas which are doubling in size within 30 years (Piorr et al 2011).

These various concepts and definitions are summarized in Table 2.

Table 3.2: Functional layers: summary of concepts & citations

PERI-URBAN CONCEPT	Example definitions	Citations
FUNCTIONAL URBAN REGION / AREA : Hinterland of economic / labour market unit:	'an urban core and the area around it that is economically integrated with the centre, e.g. the local labour market. Belonging to a commuter catchment area, FUAs represent common local labour and housing markets'	(Nordregio 2005).
'AEROTROPOLIS' Specialized / globalized transit hub: also applies to retail or leisure malls, business or science parks etc.	a metropolitan subregion where the layout, infrastructure, and economy are centered on an airport which serves as a multimodal "airport city" commercial core.	Kasarda & Lindsay 2006
PERI-URBAN AREA: Urban-rural linkage concept:	Parts of a city that appear to be quite rural but are in reality strongly linked functionally to the city in its daily activities.	Intergovernmental Panel on Climate Change [IPCC] (2019): Brenner 2015
PERI-URBAN-ISATION PROCESS Dynamic transition concept:	a process in which rural areas located on the outskirts of established cities become more urban in character, in physical, economic, and social terms, often in piecemeal fashion.	Webster 2002:
URBAN FRINGE Land-use competition concept:	… transition zone between the built-up area and the countryside… interface between the consolidated urban and rural regions: a zone of mixed land uses with competition between them.	European Environment Agency (2006 & 2017)[1] Gallent 2007
TRANSPORT EFFECTS	Automobile dependency is the concept that urban expansion cause automobiles to be favoured over alternate forms such as bicycles, public transit, and walking, in a reinforcing feedback loop	Newman and Kenworthy 1999: Kosonen et al 2016

3.2.4 A global edge city?

The role of the peri-urban and the rural hinterland in Asia is often very different to that in Europe or North America. In the Asian megalopolis type there is a focus on the rapid transition from peasant agriculture towards a globalized economic development pattern and patterns of so-called urban sprawl seen in the USA differ remarkably from China (Jones and Douglass, 2008; Ginsburg and Koppel, 2004 (Leaf, 2011; Rajan, 2017; Sreeja et al., 2017; Webster, 2011). By contrast, in the North American type there is a focus on the 'edge city' as a new kind of CBD, and the rural as a zone of enterprise and opportunity (Garreau, 1991; Daniels, 1998). The peri-urban and rural hinterland is not

[1] https://www.eea.europa.eu/themes/sustainability-transitions/urban-environment/urban-green-infrastructure/glossary-for-urban-green-infrastructure

so much a fixed thing 'out there', but highly inter-dependent and inter-woven with urban areas. Indeed, Douglas Webster (2011) suggests that it is, perhaps, fruitless to try to define the peri-urban but, rather, we need thick, descriptive accounts of the varieties of 'peri-urbanisation as a process':

> *"It is less important to define peri-urbanization, than it is to better understand the process through more comparative, systematized study at a variety of spatial scales: from the site to megapolitan scales, and from multiple perspectives, ranging from highly technical analyses of time series satellite imagery to community-based anthropological studies. Peri-urbanization is a process, not a type of urban region."*

3.3 Socio-ecological layers in the peri-urban

3.3.1 Social-ecological linkages

Human-ecosystem linkages and interactions are decisive for peri-urban land use relationships. For example, the peri-urban has aesthetic and social cultural value for a variety of people (Gallent and Andersson, 2007; Sylla et al., 2019), even those living in the urban core (Ives and Kendal, 2013). This implies that there is a cultural and place-based way of defining the peri-urban (Taylor 2011). For example, early definitions of 'exurbia' noted the tendency for the unit to be attractive for affluent middle classes in the US who were not only motivated by the cheaper house prices but the access to environmental amenities due to proximity to the countryside (Spectorsky 1955). Meanwhile, in cities such as Greater Mumbai and Johannesburg, there are a complex mix of residents including the affluent, who wish to take advantage of the cheap land values, in competition for increasingly scarce resources with existing peri-urban informal settlements and villages (Cash, 2014; Sreeja et al., 2017). Such a phenomenon has led to the characterisation of those living in Asian peri-urban areas as being 'bypassed' or 'left-behind' as the peri-urbanisation process is so complex, dynamic, and largely unplanned, that there are, of course, winners and losers (Rajan, 2017).

3.3.2 Socio-political ecology of the peri-urban

A full 'interaction menu' is shown in Section 1, for the negative impacts of peri-urbanization – climate risk / adaptation. For a more rounded understanding of 'ecological urbanization', various socio-ecological factors can be explored as positive forces, which not only increase the peri-urban population, but influence the settlement pattern, and livelihoods and lifestyles of the inhabitants. In the later stages of the Peri-cene project these potentially positive linkages, and the socio-political issues raised, are the focus of the adaptive governance agenda (see section 4 of this report). However these linkages raise challenges on distribution, access to resources, decision-making and representation, and hence the concepts of political ecology have emerged (Martinez-Alier 1999: Kaika et al 2005: Mehta and Karpouzoglou 2015).

Peri-urban areas generally contain large urban infrastructures, such as water, waste and sewage treatment, typically located away from the central urban core. The displacement of former activities, environmental impacts, and associated privatization or financialization of resources, all have significant implications for environmental justice (Kaika 2008). Meanwhile peri-urban areas offer significant climate change functions for urban areas, e.g. through green corridors or catchment-based flood management, which may be eroded by land use change and changing agricultural practices (Carter et al., 2018). The protection of such areas by ecological or spatial planning, then attracts higher income residents and visitors, in a process of peri-urban 'eco-gentrification' and polarization (Gallent et al., 2006; Ives and Kendal, 2013)

3.3.3 Socio-cultural factors in the 'post-metropolis'

From the above it is clear that the peri-urban is far from homogenous and, as a different type of urban form that is neither urban or rural, the peri-urban can facilitate new lifestyles and modes of being (Cusin et al., 2016): this calls for both technical analysis and deeper anthropological accounts (Webster 2013; Garner, 2017). Historically, some have characterised the peri-urban as an enclave of the middle classes who have access to cheap land and can perform long commutes to work in the city (XXX) or else those middle classes who cherish the ideals of living close to nature but with urban lifestyles and social networks (Luka, 2017; Vejre et al., 2010). However, the peri-urban has also been characterised as the space where the have-nots may be 'banished' to, such as the *banlieus* in Greater Paris, 'projects' and peripheral estates in the USA or UK, or shanty towns or 'resettlement zones' in India (Cusin et al., 2016). Literature from the Indian and Chinese context also describes the processes by which rural villages become encompassed or bypassed in the peri-urban spaces, which disrupts livelihoods and generates conflicts over land uses and access to natural resources (Abramson, 2016; Rajan, 2017; Sreeja et al., 2017). The consequence is that:

> 'there are many, often contradictory representations of peri-urban space, many of which have no empirical basis … the great diversity of areas studied makes it difficult to generalize, especially since there is no consensus on how to define peri-urban space and because the fragments of peri-urban life…are often dissociated from the larger spatial systems they are part of' (Cusin et al., 2016, p. 439).

Such widespread fragmentation can then be framed as a system transition in itself. For example the so-called 'post-metropolis' or 'carceral city' is not only a physical urban sprawl over huge areas of the peri-urban: it tracks the 'social and spatial effects of new urbanization processes, increasing cultural diversity, rising economic inequalities and social polarization, and changing urban forms and functions: …. the hard and soft adaptations to the new and increasingly volatile urban condition, security obsessed urbanism and simulated hyper-realities to divert attention away from contemporary urban problems' (Soja, 2011).

3.3.4 Spatial planning and governance in the peri-urban

In response to the above problems and opportunities, there is a diverse range of peri-urban planning, policies and governance mechanisms. The main governance agenda is in Section 5, so here is a brief outline of some spatial governance agendas.

One of the foundations of 20th century spatial planning, the UK Green Belt, is practiced around the world under different guises and regimes (Monk et al 2013). However in almost all peri-urban areas, there is pressure for new motorways, airports, housing, business parks and other infrastructure, and many green belt areas are damaged and polluted (Elson et al 1993: Natural England 2009). There are many arguments around the Green Belt, whether it succeeds in urban containment and compact cities, how far it raises negative side-effects to urban or rural areas, or how far it maintains the property and class hierarchy in access to land (Fairlie, 1996: Gallent, 2006: Henderson, 2005: Westerink et al 2013). On the ground, the pollution and degradation of large areas of Green Belts raises a topical agenda for a more integrated and sustainable 'eco-belt', or a climate-friendly 'eco-climatic belt' around or between cities (Ravetz, 2000: Douglas and Ravetz 2011). Overall the problem of urban development can be reframed as a zone of opportunity for new mixed uses and socio-ecological activities (Scott et al 2013).

Meanwhile rural development and landscape quality have traditionally been on the receiving end of urban expansion impacts. However there is an alternative process of adaptation of rural areas to new urbanized activities, as in the section above: with opportunities for rising values, new enterprises, and new decentralized systems for food, forestry, water and other resources. So the governance agenda has to adapt rapidly, for instance to agricultural reform relating to intensive or extensive production, as a major influence on land-use change. Urban agriculture is one of the most interesting global trends, raising questions on industrialized food chains, social enterprise and community mutual aid (Pretty, 2002: Nettle 2014). 'Ecosystems services' is a useful concept which (in principle) enables collaborative governance and re-investment for protection and adaptation (TEEB 2015: Caro-Borrero et al, 2015). There are interesting experiments in 'Payment for Ecosystem Services', and investment for natural capital (Defra 2013: GMCA 2019).

Table 3.3: Social-cultural and political-ecological layers: summary of concepts & citations

PERI-URBAN ISSUES	*Example definitions*	*Key citations*
CARCERAL CITY / POST-METROPOLIS: Social-cultural systems concepts	…a new flexible, information-rich, postfordist economy; the globalization of capital, labor, and culture; and the complementary revolution in ICT….	Soja, 2011
EX-URBIA / EX-URBS : Counter-urbanization concepts:	[…] as a particular form of amenity-driven sprawl at times reaching into the global countryside with profound effects.	(Taylor, 2011, p. 335)
'NON-PLACE' Socio-cultural experience concepts:	a landscape of 'non-places': transient, artificial, anonymous and alienated	Auge, 1999
EDGE CITY Rapid decentralization of urban functions	'Cities, because they contain all the functions a city ever has, albeit in a spread-out form that few have come to recognize for what it is. Edge, because they are a vigorous world of pioneers and immigrants, rising far from the old downtowns, where little save villages or farmland lay only thirty years before'	Garreau 2011: 4
GREEN BELT POLICIES	A *greenbelt* is a policy and land use zone designation used in land use planning to retain areas of largely undeveloped, wild, or agricultural land surrounding or neighboring urban areas.	Monk et al 2013: Scott et al 2013
ECOSYSTEMS SERVICES POLICIES	'Ecosystem services can be defined as services provided by the natural environment that benefit people'.	Defra, 2013: Gómez-Baggethun, E. et al. 2013

3.4 Analysis & modelling of the peri-urban

(Lead: UOM team / MS)

This is a short review on Identification, delineation, and mapping of the peri-urban areas through "measures", "measurements" "metrics": (see also the Annex to the D1-2 Framework report).

The peri-urban area is a product of urbanization within the global economic and socio-political settings and it creates a complex ecosystem interaction. In recent days 'peri-urban' has become a popular term over the world to define the settlement beyond the city boundary (Woltjer et al., 2014). Rural-urban interface dichotomy is one of the important research questions in the 21st-century planning, policies and management approaches. The trends of world future population growth are towards the peri-urban areas in the world's cities and towns. Since the last two decades, the conceptual literature and the hydropathical space in peri-urban areas have significantly increased. But geographically and conceptually the Peri-urban areas have no clear boundaries (Gonçalves et al., 2017) and also, there is no adequate and accurate methodology for spatial implementation and identifying these highly multi-dimensional concepts. There are no well-recognized and suitable methods for the delineation of peri-urban areas. Very few studies have tried to differentiate peri-urban areas using statistical and geospatial approaches.

Piorr et al., (2011) for the first time classified the rural-urban region in Pan-European level for the PLUREL project. The PLUREL project define the Peri-urban areas for Europe as 'discontinuous built development, containing settlements of less than 20,000, with an average density of at least 40 persons per km^2 (averaged over $1km^2$ cells). In the PLUREL project peri-urban areas have been identified from the two classes 'urban fringe' and 'urban periphery' by their spatial classification, namely 'rural-urban region' (RUR). Paul et al (2010) used night-time satellite imagery for mapping urban and peri-urban areas of Australia. They have used the population-weighted measure of urban sprawl to identify the threshold of Peri-Urban areas. The research suggests that 82% of the population lives in urban areas and 15% lives in peri-urban in Australia.

Cusin et al., (2016) define peri-urbanization as a 'discontinuous sub-urbanized space with a mixed rural-urban interface'. They have developed a study on peri-urban space in France using a multiscale statistical approach, using French census data from 1968 to 2011.

Gonçalves et al., (2017) differentiated the peri-urban areas using a transdisciplinary approach for the identification of typologies of peri-urban areas for the Lisbon Metropolitan Area (LMA), Portugal. The study is based on the assumptions that more than one type of peri-urban region around an urban core can exist. The study linking the physical, economic, social and personal aspects, is needed to capture the intrinsic variability and the complexity of the peri-urban character.

Danielaini et al. (2018) provides more accurate rural-urban definitions for peri-urban delineation a case study at the Cirebon Metropolitan Region (CMR), West Java. They have used a total of 11 social, economic and spatial variables directly or indirectly related to ecohydrological settings of the rural-urban interfaces. Using both GIS and statistical techniques for this case study, eight classes of rural-urban interfaces have been identified, as a practical framework for delineation of peri-urban areas.

Balk et al., (2018) has used the time-series of the Global Human Settlement Layer (GHSL) for 1990–2010 along with the census-designated urban blocks to understand the consistent urban proxies for the United States. They have classified the US settlements into three categories. Firstly, the urban land which has more than 50% built-up, and people living on such land within the census boundary. Secondly, the Peri-Urban areas which have 30% of the census-designated urban population and with less built-up areas.

One recent case study on classifying and mapping peri-urban areas was done by Karg et al. in 2019 for rapidly growing medium-sized Sub-Saharan African cities in Ghana. This study used a quantitative and multi-dimensional methodology using three core elements a) urbanicity index, b) livelihood and access to urban services and c) land use dynamic. To fulfil this objective, they collected data from an extensive household survey, satellite imageries and various secondary layers in different spatial scales. The findings of this study revealed that the peri-urban consists of the space between the inner peri-urban and outer peri-urban areas. Hui, and Wescoat (2019) visualized the peri-urban and 'rurban' areas to identify the water condition in this transition zones. They have used GIS based semi structural interviews to identify the peri-urban and 'rurban' water conditions.

The concept of peri-urbanization is very different for the global north and global south. Also, peri-urban development in the developing countries is very rapid compared to the developed countries. So a globally relevant spatial classification of peri-urban areas is a challenge, for instance to compare peri-urban Bangladesh with densities of over 1000 persons/km2, with peri-urban mid-west USA, with densities of 10-20 p/km2 (Newman & Kenworthy 2001). The 'PCAT' ('Peri-Cene Analysis Tool') is a first attempt to identify in a practical sense the global peri-urban areas.

3.4.1 Mapping the peri-urban baseline

(this section also reported in D1-3 with example mapping)

Starting with the question – 'where is the peri-urban?' – the Peri-cene takes a practical approach, building on the JRC-GHSL (Global Human Settlements Layer) system of urban mapping - http://ghsl.jrc.ec.europa.eu (Pesaresi 2016). The peri-urban mapping results depend on the unit size and calculation method, so a final 'objective' definition is not feasible. In response the Peri-cene takes a simple pragmatic approach, where the peri-urban mapping / definition is not a final answer, but the start of discussion with local experts and stakeholders.

The Peri-cene method extends the GHSL system to focus on 2 further bands of population density: 50-125 and 125-300 p/km^2. It also includes the open land / rural type of <50p/km2. It then places these in geographical context of proximity to the main urban centres, ***'near-urban: further-urban: ex-urban / peri-rural'.*** For detailed case studies the proximity can be calculated as a 'potential' or urban gravity field (see WP2 working paper). If local calculations are not available, we draw a 20km circle for the inner urban, and 40km circle for the outer limit (for mega-cities a further 60km radius may be also relevant). These circles have been checked against the proximity calculations and show a good fit to the iso-lines (especially for mono-centric city-regions). They also correspond to the 'theory of urban fabrics' with 3 types of urban form: walking city (<2km radius), transit city (<20km), and automobile city (<40km) (Newman et al 2016). By comparison, the Atlas of Urban Expansion focuses

on built up area, with bands of 'urban' (50-100%), 'suburban' (25-50%), and 'rural' (0-25% built up): a previous scheme identified a 10% band so it would be possible to identify a 'peri-urban' 10-25% band. (Angel et al 2016).

The summary here at *Table 1* shows the 8 main peri-urban types as combinations of:

- density range bands: 0-50, 50-125 and 125-300 p/km2,
- proximity range from *'near-urban: further-urban: ex-urban / peri-rural'*.

Table 3.4: Summary of basic peri-urban types

	'NEAR URBAN' ***(main urban fringes)*** ***<20km ('medium potential' / inner gravity field)***	***'FURTHER URBAN'*** ***(main urban hinterland)*** ***20-40km (or 'low potential' / outer gravity field)***	***'EX-URBAN / PERI-RURAL'*** ***(other areas)*** ***Outside main urban gravity fields***
HIGHER DENSITY: ***(125-300 inhabitants / km2)***	***a) 'Urban edge'***: fringe space in high density areas	***d) 'peri-urban settlement'***: Larger satellites, higher density sprawl / ex-urbs	***g) peri-rural higher density*** *small / scattered settlements*
LOWER DENSITY: ***(50-125 inhabitants / km2)***	***b) 'Urban fringe':*** Scattered settlements / sprawl near urban area	***e) 'peri-urban hinterland':*** Smaller satellites & further / lower density sprawl	***h) peri-rural lower density*** *small / scattered settlements*
RURAL / OPEN LAND: (0-50)	***c) 'Urban greenspace':*** open land / forest / other, close to / within main urban area	***f) 'peri-urban open land':*** larger spaces with low-zero populations in the hinterland	-

This typology can then be linked to various parts of the literature:

a) 'Urban edge': literature on the fringe, e.g. Scott et al 2013;

b) 'Urban fringe': literature on suburbanization e.g. Phelps 2013;

c) 'Urban greenspace': literature on green infrastructure, e.g. Ravetz 2011;

d) 'peri-urban settlement': literature on FUAs, e.g. Nordregio et al. 2005

e) 'peri-urban hinterland': literature on sprawl, e.g. Reckien and Karecha 2007;

f) 'peri-urban open land': literature on rural-urban interfaces: e.g. Simon 2005

g) peri-rural higher density small / scattered settlements: literature on 'ruralization', e.g. Rajan 2019.

4 Climate risk & vulnerability

(lead: IGCS team with AC)

4.1 Introduction

Human-induced global warming or climate change refers to the average rise in surface temperatures that are the consequence of anthropogenic activity. Article 1 of the United Nation Framework Convention on Climate Change defines it as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

The effects of climate change in the form of extreme weather and other climatic hazards on human and natural ecological systems are referred to as climate impacts. These are typically expressed as the combined effects on ecosystems, economies, human and non-human lives, livelihoods, social and cultural systems and infrastructure over short and long time periods. The physical events that lead to these impacts may take the form of floods and droughts, sea level rise, desertification, landslides, forest fires and so on.

Associated with the questions surrounding the definition of climate impacts and indicators to measure them are a large set of issues having to do with the identification of vulnerability and risks, as well as coping strategies, generally referred to as adaptation.

4.2 Climate impacts, risks, vulnerability and adaptation

4.2.1 Overview

The literature on climate change impacts and adaptation is vast and is addressed in a separate Working Group (WG II) of the Intergovernmental Panel on Climate Change (IPCC). In its five assessments so far (and the sixth, which is in progress), WGII has generated evolving frameworks to interpret the complex of concerns associated with climate change impacts, risks, resilience, vulnerability and adaptation.

Principally because climate change impacts occur at multiple timescales and geographical scales and affect human and natural systems in manifold, interactive ways, there are competing definitions of the terms used in this subsection. There is, nevertheless, widespread recognition that severe shifts in the normal life of a community or ecosystem can be expected to take place as a result of climate change and that these could be manifested differently for different sections based on the level or exposure and prior states. Furthermore, adverse impacts may require emergency measures or longer-term adjustments, leading either to full recovery or critical and irreversible change.

In some cases, harms ensue as the emergent outcomes of multiple conditions, such as poverty, land-use change, industrial pollution and climate change, making it very difficult to separate out any one set of causes as being primary to the outcome. These interlocking conditions and the difficulty of attributing severe weather events or their consequences directly to the accumulation of

anthropogenic greenhouse gases in the atmosphere create special challenges for characterizing climatic risk.

At the same time, it is relatively easier to find practical ways to improve the ability of communities and ecosystems to deal adequately with changes taking place in their environment. The IPCC appears to acknowledge the importance of response over definitions and has adopted a risk and resilience framework over its earlier emphasis on vulnerability and adaptation… Since 2012, IPCC has reframed climate change adaptation to focus on risk rather than vulnerability. Such a move intends to harmonize the climate change adaptation community with those working in allied disciplines, such as disaster risk management. Those in the climate change adaptation community have largely used 'vulnerability' as their frame for understanding and responding to climate change which is at odds with more mainstream understandings of exposure and disaster where the preferred term is 'risk' (Connelly et al. 2018).

In the next section, we discuss some of these terms: also, key definitions and citations are shown in Table xxx.

Table 4.1: Climate risk and adaptation: summary of concepts & citations

CLIMATE ISSUES	*Example definitions*	*Key citations*
Climate change impact		
Climate change risk	"the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values."	IPCC WGII, AR5: 199 Connelly et al (2018)
Climate vulnerability	"characteristics of human or social-ecological systems exposed to hazardous climatic (droughts, floods, etc.) or non-climatic events and trends (increasing temperature, sea level rise)	IPCC WGII, AR5, p. 1050
Climate change adaptation	'process of adjustment by societies and natural systems to the actual or anticipated effects of climate change'	
Climate change resilience	'the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation'	Leichenko 2011

4.2.2 Concepts

Climate **risk** is difficult to pin down because there are multiple interpretations of the word 'risk'. In formal, probabilistic terms, it can be represented as the impact-weighted likelihood of hazards. It is

in turn the function of vulnerability, exposure and hazard strength or impact. This definition thus raises the need to specify vulnerability and exposure as well. A final term in this pantheon is 'adaptation', which includes methods of coping as well as the (adaptive) capacity to do so. More confusingly, there turn out to be multiple ways of understanding each of these terms (Hansson, 2004; Althaus, 2005; Hansson, 2010), vulnerability (Weichselgartner, 2001; O'Brien et al., 2007), and adaptation assessments (Adger et al., 2009).

The IPCC WGII describes risk as "the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values." The breadth of this interpretation is indicative of an acknowledgement of the expanse of the ontological and ethical landscape in which the 'risks' of climate change lie. When values are expressed in terms of money or other perfectly substitutable useful goods, they express a certain point of view as to what might constitute their loss. A different point of view might, for instance, express climate risk as the loss of lifestyle, loss of social and cultural practices and their memory, loss of homeland and resulting statelessness, and so on (Hansson 2005; Catherine Althaus 2005; Hansson 2004).

Risks, in the IPCC's definition, can therefore be described in quantitative and qualitative elements. Quantitative assessments of risk are now understood through having multiple dimensions and attributes. Qualitatively, it is seen to be socially constructed, implying that there may be different cultural and positional ways of estimating risk, rather than a commonly defined or constructed notion of risk. For example, Article 2 of the UNFCCC convention that calls for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" is a framing that invokes both scientific analysis and human values. Hence, risk posed by climate change to society is not just the quantitative risk measured in terms of climate impacts in probabilistic terms but is also essentially a value-based judgement on what is "dangerous" and how much danger is acceptable or unacceptable. People and societies may perceive or rank risks and potential benefits differently, given diverse values and goals (AR5, WG II, p.3).

The term **vulnerability** is equally complex and tries to capture the propensity of the system to be adversely affected by climatic changes. The IPCC considers the sensitivity and capacity of human societies and natural systems to respond to short and long-term climate events and their outcomes. As defined by the IPCC, vulnerability refers to multi-dimensional and time-dependent "characteristics of human or social-ecological systems exposed to hazardous climatic (droughts, floods, etc.) or non-climatic events and trends (increasing temperature, sea level rise)" (AR5, WGII p. 1050). This too has changed from an earlier definition in the Third Assessment Report, where it was characterized in terms of a formal function of exposure to climate hazards and the sensitivity and adaptive capacity of the system. Treated now as a multi-dimensional concept, increased attention is paid to the relation to structural conditions of poverty and inequality. "Key" vulnerabilities are associated with especially dangerous predispositions of sites and regions, particularly in circumstances where prevailing conditions of poverty, unemployment, lack of access to services and land degradation, water stress or loss of biodiversity interact with climate stressors (AR5, WGII p. 179).

Adaptation relates to the process of adjustment by societies and natural systems to the actual or anticipated effects of climate change. Adaptive measures can be constituted in terms of incremental

(gradual) or transformational change. Incremental adaptation seeks to maintain the basic integrity of institutions and activities at a given geographical scale. Transformational adaptation assumes that the fundamental attributes of the system need to be altered to create new system states that can respond more effectively to climate change.

Understanding the ability of the system to adapt to climate change requires assessment of options for change, their benefits, costs and feasibility.

Resilience is a term that has gained traction in the literature, partly as a result of the growing recognition of the multi-dimensional character of climate change risk. Much of this traction has recently revolved around the domain of cities and climate change.

The IPCC definition is that resilience is "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation."

Enhancement of resilience is being recognised as a key goal for both adaptation and mitigation efforts in cities and urban regions. Links between resilience and other concepts such as vulnerability, sustainability, adaptation are also being explored (Leichenko, R, 2011). However, there are several emerging concerns regarding the use of resilience as a framework for addressing climate risks in cities, primarily relating to costs and financing of resilience and equity concerns. The first concern related to differing capacities of cities to pay for resilience. Ayers (2009) particularly draws attention to the need for international sources of funds to build and promote resilience in low and middle income countries highlighting concerns around external funding undermining self-sufficiency of local communities. The second issue raises concerns around the uneven benefits of resilience where resilience being promoted in some locations may come at the expense of others. Other studies have pointed out the importance of considering the relationship between poverty and resilience in order to ensure that these efforts do not reinforce existing inequalities or create new ones (O'Brien et al, 2009).

4.2.3 Risk assessments and adaptation, impacts, vulnerability

Climate change risk assessment involves formal analysis of the consequences, likelihoods and responses to the impacts of climate change and the options for addressing these under societal constraints (Adger et al, 2018). This and other climate, impact, adaptation and vulnerability (CIAV) assessments are used in climate change decision making processes, with particular relevance for developing adaptation policy. Because all decisions on CIAV are affected by uncertainty and focus on valued objectives, these can be considered as decisions involving risk (e.g., Giddens, 2009).

Risk assessments are used across many disciplines, however in order to be used for climate change, they need to address complexities inherent to climate change and integrated with existing methodologies. According to Connelly et al (2018), these need to be fully cognizant of geographical variability, environmental processes and socio-economic vulnerabilit**y** in order to be of use with respect to climate change.

Decision making for climate change was previously based on models that assumed a cause-and-effect process: whereby increasing greenhouse gas emissions cause climate change, resulting in changing impacts and risks, potentially increasing vulnerability to those risks. The resulting decision-making guidance on impacts and adaptation followed a rational-linear process that identifies potential risks and then evaluates management responses (e.g., Carter et al., 1994; Feenstra et al., 1998; Parry and Carter, 1998; Fisher et al., 2007), a top-down approach. These linear methods have been challenged for their narrow scope and their inadequacy in addressing diverse contexts within which such decisions are actually made, overlooking many cultural and behavioral aspects (Smit and Wandel, 2006; Sarewitz and Pielke, 2007; Dovers, 2009; Beck, 2010). Conventional approaches to risk assessment are further challenged by the significant temporal and spatial dynamics of climate change and through the interaction of multiple risk factors (AR5, WG II, p. 199).

CIAV assessments are expanding from science-driven linear methods to a wide range of methods drawing from many disciplines. Many different risk methodologies, such as financial, natural disaster, infrastructure, environmental health, and human health, are relevant for CIAV decision making. Each methodology utilizes a variety of different tools and methods.

AR4 endorsed iterative risk management as a suitable decision support framework for CIAV assessment because it offers formalized methods for addressing uncertainty, involving stakeholder participation, identifying potential policy responses, and evaluating those responses (Carter et al., 2007; IPCC, 2007b; Yohe et al., 2007). Iterative risk management involves an ongoing process of assessment, action, reassessment, and response (Kambhu et al., 2007; IRGC, 2010) that will continue—in the case of many climate-related decisions—for decades if not longer (National Research Council, 2011). Such an iterative format can be suitable for policy responses framed under a resilience framework owing to the range of potential risks that are largely unpredictable. Although a resilience assessment is different from a traditional risk assessment, it can be embedded into a longer-term iterative risk management process which is made up of several different stages. Climate change response can be linked with sustainable development through actions that enhance resilience. Mainstreamed adaptation, disaster risk management, and new types of governance and institutional arrangements are being studied for their potential to support the goal of enhanced resilience (AR5, WG II, p. 198).

The earlier models which used linear, straightforward methods can work well in simple, well-bounded contexts such as within a cause-and-effect relationship. Complex contexts require greater attention to process. However, when complex environments interact with conflicting values they become associated with "wicked problems". Wicked problems are not well bounded, are framed differently by various groups and individuals, harbour large scientific to existential uncertainties and have unclear solutions and pathways to those solutions (Rittel and Webber, 1973; Australian Public Service Commission, 2007). This level of uncertainty, referred to as "deep uncertainty" is hard to quantify (Dupuy and Grinbaum, 2005; Kandlikar et al., 2005).

In such complex situations, sociocultural and cognitive-behavioral contexts become central to decision making. This requires combining the scientific understanding of risk with how risks are framed and perceived by individuals, organizations, and institutions (Hansson, 2010). For that reason, formal risk assessment is moving from a largely technocratic exercise carried out by experts to a more participatory process of decision support (Fiorino, 1990; Pereira and Quintana, 2002; Renn, 2008),

although this process is proceeding slowly (Christoplos et al., 2001; Pereira and Quintana, 2002; Bradbury, 2006; Mercer et al., 2008).

CIAV decision making also involves ethical judgments expressed at a range of institutional scales. Recognition of local and indigenous knowledge and diverse stakeholder interests, values, and expectations is being considered as fundamental to building trust within decision-making processes.

Another type of risk that is given consideration in the 5th assessment report are risks associated with taking action (e.g., will this adaptation strategy be successful?) and the broader socially constructed risks that surround "climate change" (e.g., fatalism, hope, opportunity, and despair). Also, McDermott & Surminski (2018) explore the interplay of climate risk assessment and normative decision-making at an urban level. This work shows that, throughout any decision process, there are points where objective risk data meet subjective prioritization and normative judgements, and potentially controversy, for example, when setting 'acceptable risk levels' and identifying 'adequate' protection levels, which can lead to controversy over competing priorities and differing perspectives on what should be given precedence. Recognizing these intersections early is important for those who conduct the risk assessment as well as those who use it.

4.2.4 Overview of the IPCC Risk-based Conceptual Framework.

(AC)

In a special report (SREX) on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation, the Intergovernmental Panel on Climate Change (IPCC 2012) altered their conceptual framework on climate change, from a vulnerability-based framework to a risk-based framework (IPCC 2012). The risk-based conceptual framework was subsequently adopted in the IPCC's Fifth Assessment Report [AR5] (IPCC 2014) which incorporates the traditional definition of risk as the multiplication of probability and consequences. The revised IPCC risk-based framework presents a functional relationship between the elements of risk, which are broken down to reflect the hazard, exposure, and vulnerability (1; Figure X).[2]

Risk (R) = *ƒ* (Hazard (H),* Exposure (E), * Vulnerability (V)) (1)

[2] Key' and 'emergent' risks are also distinguished in the IPCC's AR5 terminology. Key risks may have severe consequences for the system of interest (people, assets) due to high exposure or high vulnerability. Emergent risk, on the other hand, has a strong temporal component since it emerges from the interaction of different phenomenon over time, e.g. reduced food supply and migratory patterns. 'Associated risk' is also identified by the IPCC AR5; associated risk relates to indirect impacts of an extreme weather event or climate change; this could be considered to be close to the notion of 'cascading effects'.

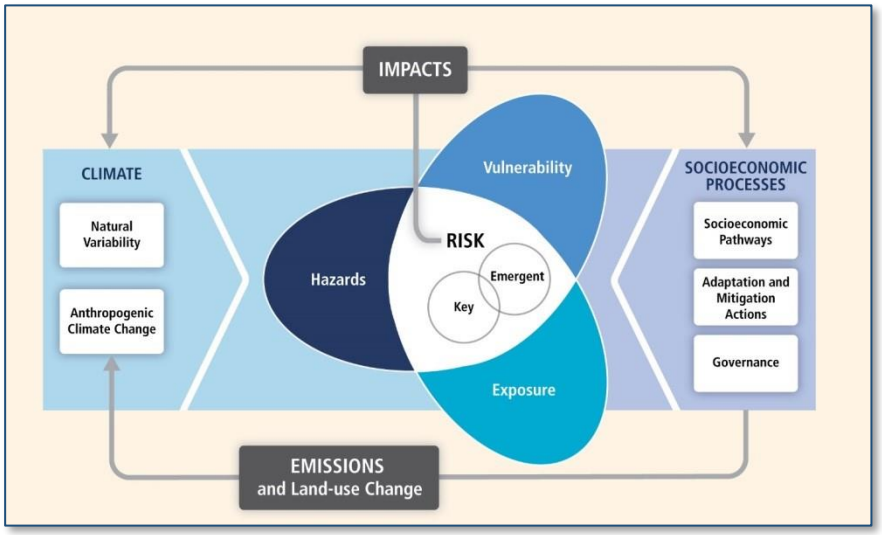


Figure 4.1: Conceptualisation of risk by the IPCC, AR5, WG-II, Ch. 19.

The main definitional change is in the removal of 'exposure' from the definition of vulnerability. Pre-AR5, vulnerability was considered to be to be a function of hazard, exposure and sensitivity [Vulnerability = f (Exposure, Sensitivity, Adaptive Capacity)]. Within the climate change literature, the emphasis of early work (so-called 'first-generation') was on biophysical vulnerability which tended to focus on observed and projected changes in climate that may exacerbate exposure and sensitivity (Füssel and Klein, 2006). However, developing knowledge drew attention to the ways in which existing socio-economic circumstances interact with climate change, and led to a distinction between outcome vulnerability[3] and contextual vulnerability[4] (O'Brien 2007). The separation of exposure from vulnerability may also be intuitive in some sectors; an electricity transmission line, for example, is only exposed to windstorms if it is above ground (McCord et al 2015: p. 48). In addition, the probability of an impact occurring may be affected by enacting vulnerability reduction measures.

Several reasons may be given that prompted this change:

- To bring the study and practice of future climate change adaptation into line with present-day disaster risk management (EEA 2012).
- To reflect more nuanced understandings of the vulnerability concept that consider socio-economic circumstances as well as biophysical vulnerability (EEA 2012).
- To make it easier for risk managers to identify and separate out exposure-reduction measures from vulnerability-reduction measures when planning to adapt to climate change (Connelly et al. 2018)
- To make it easier for policy makers to consider climate change alongside a broad range of risks that need to be taken account of (e.g. terrorism, economic failure, and so on) (Connelly et al. 2018).

[3] Outcome definitions refer to the residual level of vulnerability once adaptive capacity is subtracted from exposure and sensitivity to climatic stimuli. Outcome definitions are typically quantitative, look to the future, are top-down as they stem from global climate models (Hinkel 2011).

[4] Contextual vulnerability focuses on the characteristics of a given system that exist before any hazard affects it (O'Brien et al 2007). Thus, vulnerability is inherent in the system of interest, and climate change is only one of other interacting stressors (or drivers) on that system. Characteristics may be socio-economic (low income, mobility issues); institutional (funding, knowledge, policies); technological (design weaknesses, redundancy); and biophysical (extreme weather events as well as climate change).

4.2.5 Application of the risk framework

The above revised scheme has been applied to the Peri-cene Framework (D1-2), where the 'Causal model' provides a basic structure to help describe a simple generic 'impact chain'. In this case the 'risk' includes:

- hazard from climate change
- exposure from peri-urbanization
- vulnerability in the physical and socio-economic conditions
- 'adaptive capacity' in the qualities of governance

In reality there is complexity on all sides: the physical impacts of climate, the exposure of populations, the socio-economic conditions and so on. The key features of such complexity can then be identified in the Framework 'synergistic model'.

4.3 Climate change and peri-urbanization

The relationship between peri-urbanization and climate change covers aspects of mitigation, impacts and adaptation, each with several dimensions having to do with the built environment, energy services, food production, land management, transport networks and water security. In many respects, peri-urbanization and urbanization have the same impacts of higher energy (and therefore, potentially, carbon) intensity with growth and greenhouse gases associated with waste production and land-use change (Simon 2008; Ravetz et al 2013). In addition, however, peri-urban expansion can place additional burdens on urban footprints through urban land 'teleconnections' where deforestation, water extraction or cropland changes in the hinterland will not only have an ecological impact in the remote location but also alter flows and demands in the core (Seto et al 2012).

The IPCC does not generally distinguish between urban and peri-urban areas in its Fifth Assessment Report. In Working Group II, urban and rural areas are addressed in two separate chapters, although there are references to 'peri-urban; and 'hinterland' in both (Revi et al 2014; Dasgupta et al 2014). In addition, some regional chapters, notably the ones on Africa and Asia, point to the continuity between rural and peri-urban regions in the context of rapid economic change, migration and the depletion of ecosystem assets.

Throughout the report, peri-urban areas are highlighted for enhancing food security and bolstering ecosystem services, especially because there is likely to be more land available for experimentation than in dense urban cores. What are not directly referenced in any chapter are drivers of peri-urban dynamics in different regions, overlapping zones of governance and land tenures, and spatial economics. The chapter on Rural Areas, however, does cite literature (Bowyer-Bower 2006; Simon 2008) to highlight the challenges of making a simple rural-urban dichotomy, bringing up the need to have special considerations at the peri-urban fringe.

The Special Report on *Climate Change and Land* (2019) is significant in its coverage of a wide range of terrestrial ecosystems in their different land forms and uses. Nevertheless, it too does not explicitly speak to the borderland character of peri-urban regions, whose mottled forms of commercial parks, human settlements, farmland and forests present features that are distinct from both cities and other well-defined biomes. Still, the report's definition of sustainable land management is a useful starting point to create a baseline on peri-urban resilience. It is "the stewardship and use of land resources, including soils, water, animals and plants, to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" *ibid.,* p.1.

This is relevant because the report highlights the dangers that are pertinent across a wide range of land-uses: biodiversity loss and desertification, food security, freshwater depletion, land degradation and pollution. Each of these is has both proximate (e.g., changes in farming practice or loss of cropland due to urban expansion) and remote (e.g., demand for resources) drivers and are amplified by climate change. The report especially recognizes that cities are highly vulnerable to perturbations to food production and loss of ecosystem services in urban and peri-urban areas (Lwasa et al. 2014, 2015; Padgham et al. 2015; Lee et al 2015)). It notes that urban and peri-urban agriculture have many advantages for both climate mitigation and adaptation, including lower transport costs for produce, potentially re-using wastewater and avoiding methane emissions at dump sites, reducing the heat island effect, increasing biodiversity, slowing down runoff and increasing subsurface rainwater collection (Lwasa et al 2015; (Lin et al. 2015) Kumar et al. 2017).

4.4 Water, food and climate change nexus

While the idea of the water-energy-food nexus was initially meant to contribute to UN sponsored Rio +20 Conference in 2012, nevertheless, this ideation emerged in response to climate change, population growth, and urbanisation (Hoff, 2011). The nexus has drawn tremendous interest in MDBs as major rivers especially in Asia and Africa have potentially provided both challenges and prospects for addressing conflicting demands across sectors and among users in the face of climate change and water security (ADB, 2011, 2013). Besides frequently occurring international / regional conferences (co-organised by academic institutions), research initiatives and projects around the world on the water-energy-food nexus (WEF), the focus on nexus can be grouped into four sub-groups: water-food; water-energy; water-energy-food and water-energy-food-climate change (Endo 2017).

Despite no clear definition of the term 'nexus', more than 79,80,000 hits on Google search are found searching the phrase 'water-food-energy-climate nexus' (as of September 2, 2019). Further, this has been narrowed down to 82,000 hits by using the phrase 'water-food-energy-climate nexus in peri-urban areas'. Literature are based on activities on reducing water consumption for producing food and increasing efficiency of water resources for producing food. Environmental activities of the water-food nexus included examining food imports and the virtual water nexus (Qadir et al, 2007), improving the efficiency of utilization of green water, preventing depletion of residual soil moisture in the field after crop harvest, and reducing the use of water through a shift to drought resilient crops in India (Kumar et al, 2012). Social, economic and governance approaches were discussed with the environmental activities such design of extension and training programs by stakeholders,

microfinance model, public-private partnership and pro rata pricing system of electricity used in the farm.

4.4.1 Urban and peri-urban foci on water-food-climate linkages

Gragg introduces new environmental, social and economic perspectives and practices that are responsive to the rapidly urbanizing agricultural food system (Gragg, 2018). Using four case studies of Newark, Detroit, Mexico City and Southern Belize, the paper presents a conceptual model of the urbanizing food-water nexus on the notion that the food not only the primary element in the formation of human settlements, but also food as a component of the water and energy cycle is vital for all life on our planet. Under urban challenges of the nexus and its local global context in *The Water, Food, Energy and Climate Nexus Challenges and an agenda for action*, series of articles delves into urban area and its hinterland, demonstrating that this is where the Nexus needs managing (Dodds and Bartram, 2016). While urban agriculture is an increasingly popular practice in cities worldwide, study on several developing countries postulate strategies to integrate city farming into the urban landscape (Mougeot, 2005).

Among others, study of virtual water/water footprint by scholars can be intended to contribute to the nexus study. Despite the virtual water concept Initiated in early 1990s (Allan, 1998) and studied at global scale (Chapagain and Hoekstra, 2004; Hoekstra and Hung, 2002), at national, regional and river basin scales (Vanham and Bidoglio, 2014), there has been less number of research and understanding of urban and peri-urban linkages on nexus. Studies of city level water footprint assessment includes case studies from developed and developing countries on agriculture product imported to cities (Vanham, 2013; Vanham, Gawlik, and Bidoglio, 2019; Zhao, He, and Zhang, 2015) and conservation of water by changing over all diet at city scale (Zhao et al, 2015). While most of the studies indicating that urban cities are consuming 20 times more virtual water than physical water (Manzardoa et al, 2016; Rao, 2019; Hoff et al, 2014), there is an absence of body of work on the food production in peri-urban areas that feed cities, in other words the nexus of energy-water-food in the peri-urban context has been under explored.

5 Peri-urban adaptive governance

5.1 From 'government' to 'governance'

(KTH lead)

The emphasis on governance (rather than government) has increased over the last three decades as the influence of the state has been eclipsed by neoliberal and globalisation agendas as well as an increasing dissatisfaction with conventional, state-led approaches to planning, policymaking, and regulating (Harvey 1989, Jessop 1998, 2000, Cars et al 2002, Healey 2004, Meadowcroft 2009). Governance can be understood as a distributed activity 'involving a multitude of variegated public and private actors and relationships that operate through multiscalar and multiactor networks' (Rosenthal and Newman 2019: 1438). It intentionally moves away from traditional administrative routines and instead recognises the state as a relational and provisional achievement (Rosenau 2000, Painter 2006, Allen and Cochrane 2010, McGuirk and O'Neill 2012, Castán Broto 2017). Baker and McGuirk (2019: 4) argue that 'rather than operating with coherent identities, agenda and capacities to exert authority, states are complex terrains of contestation marked by incompleteness, compromise and regular failure.' The notion of governance cuts across many of the United Nation's Sustainable Development Goals and is specifically addressed in SDG 11 (Sustainable Cities and Communities), SDG16 (Peace, Justice and Strong Institutions), and SDG 17 (Partnerships for the Goals).

With respect to cities, the notion of governance is helpful for understanding the multiple ways that a range of local and regional stakeholders influence urban development processes and outcomes. It recognises that the steering of urban development involves multiple individuals and organisations rather than a sole reliance on the public sector as the principle agent of change (Dean 1999, Rutland and Aylett 2008, Aylett 2010a, Wamsler and Raggers 2018, Baker and McGuirk 2019, Evans 2019). For some, this emphasis on governance provides multiple opportunities to enhance democratic principles, accountability and transparency of decision making (Kearns and Paddison 2000, Bardhan 2002, Cheema 2007) while for others, it is a negative consequence of the rise of global neoliberalism and the retreat of the welfare state (Harvey 1989, Swyngedouw 2005, Frantzeskaki et al 2016). In any case, governance has emerged as a central tenet to realising more sustainable and resilient futures at global, national, regional, and local scales.

5.2 Adaptive climate governance

The earliest forms of climate governance emerged in the late 1980s and early 1990s as the issue of climate change emerged as a global discourse (Bulkeley and Castán Broto 2013). These efforts often relied on traditional mechanisms of local and national government bodies (e.g., politics, regulations,

and incentives) and a singular focus on mitigation (Anguelovski and Carmin 2011). However, climate governance has evolved significantly over the past decade and there is now a greater push to involve an expanded group of actors that are both internal and external to the public sector and to focus not only on mitigation but also adaptation processes (Carmin et al 2012). Wamsler (2017: 148) notes that 'there is widespread consensus that the establishment and implementation of adaptation strategies requires the involvement of different stakeholders and innovative ways to unite their efforts.'

The prominence of *adaptive governance* is extensively recognised in the field of climate change adaptation, disaster risk reduction and ecosystem resources management (Chaffin, Gosnell, and Cosens, 2014; Dietz, Ostrom, and Stern, 2003; Munaretto, Siciliano, and Turvani, 2014). Climate change scholars often refer to *adaptive governance* that can be defined as 'decision-making systems comprising formal and informal institutions and social networks that are able to adapt in the face of uncertainty' (Boyd and Juhola 2015: 1235; Shinn 2016). Adaptive governance is a 'muddling through' strategy that can more effectively embrace the uncertainties and instabilities posed by climate change as well as the messiness of governance and the challenges of navigating disorder (Pelling 2011, Aylett 2013b, Castán Broto 2019). Adaptive governance relies less on political leadership than on horizontal collaboration and self-organisation directed at the orchestration of interests, the persuasion of stakeholders, and the execution of integrated actions (Bennett et al 2016, Castán Broto 2019) and to 'steer cities towards socially desirable goals (sustainability, resilience, social equity, safety) within complex and ever-changing circumstances' (Patterson and Huiteema 2019: 375). Collin (2019) argues that a committed political leadership in Odisha (India) was able to adopt adaptive governance, and that became a successful example of disaster risk reduction and climate change adaptation. Brunner and Lynch (2010) prescribes that adaptive governance builds on existing resources, community interest and political will to address climate change.

A key element of adaptive governance is the development of *adaptive capacity* which refers to 'the ability to respond to challenges through learning, managing risk and impacts, and developing new knowledge and devising effective approaches' (Marshall et al 2010: 5). Transdisciplinarity and democracy are key characteristics tenets of adaptive capacity that afford public, private, and civil society actors to contribute knowledge and capacities through processes of shared learning and action (Wamsler 2017). It recognises that conventional approaches to problem-solving are inadequate (Frantzeskaki et al 2016). Adaptive capacity is used to 'enact unconventional governance arrangements, create novel learning opportunities and provide sources of inspiration for broader change' (Patterson and Huiteema 2019: 378).

The concepts of adaptive governance and adaptive capacity align nicely with climate change challenges because they recognise the need for continuous reflexivity and reflection among multiple stakeholders (Folke et al 2005, Meadowcroft 2009, Baird et al 2014, Wamsler 2017, Wamsler and Raggers 2018). As Patterson and Huiteema (2019: 375) note that 'urban governance systems need to be adaptive to deal with unfolding uncertainties, dynamics and pressures of climate change' while Wamsler and Raggers (2018: 82) describe adaptive governance for climate change adaptation as 'an emerging research field that strives to understand the role of institutional arrangements and collaboration in adapting to climate change'. It recognises that conventional policy approaches that frequently focus on individual, stand-alone issues and interventions are inadequate to address the inherent messiness of adaptation challenges.

There is no one-size-fits-all or standard approach to governing climate change adaptation but instead a multitude of approaches that are context and actor specific (Anguelovski and Carmin 2011). However, a common approach to adaptive climate governance involves public-private partnerships comprised of government, businesses, and third sector organisations (Aylett 2010a, 2013b, Anguelovski et al 2014). These actors act as champions to construct and maintain collective agendas by aligning interests and articulating future visions that are shared by all (Carmin et al 2012, Chu et al 2017). It is understood that adaptation is both multi-level and multi-scalar, and that it requires negotiation between internal and external priorities and drivers (Anguelovski and Carmin 2011). In many ways, adaptive climate governance serves as a fresh and radical approach to address the messy and constantly changing conditions of contemporary cities as they experience climate change and attempt to enact adaptation strategies (Castán Broto 2019).

Not surprisingly, there are many challenges to adaptive governance. Local governments struggle with financial issues, institutional lock-in and path dependencies, political infighting and competing priorities, divergent visions and confusion over responsibilities (Aylett 2013a, Anguelovski et al 2014, Chu et al 2017). Meanwhile, there is often a mismatch between the geographies of climate risks and the remit of engaged stakeholders (Anguelovski and Carmin 2011, Castán Broto 2017). In addition, the recasting of decision-making structures and collective responsibilities raises questions about who has ownership and control over climate change priorities (Chu 2018). Patterson and Huiteema (2019: 392) note that 'the urban governance of climate change is both crowded with many actors having authority relating to adaptation (e.g., blurred and overlapping roles of National, Regional, and Municipal Governments), but at the same time somewhat of a void with a lack of clarity over specific roles, responsibilities, and leadership.' Thus, adaptive governance threatens to abdicate collective responsibility rather than enhance it (Aylett 2010a).

Ultimately, adaptive climate governance suggests the need for transformative changes in the way that stakeholders conceptualise and respond to adaptation as well as mitigation and related issues (Pelling 2011, Wise et al 2014, Castán Broto 2017). Rather than advocating for transition processes that involve deliberate and incremental changes, transformations involve the realignment of political structures to completely reimagine existing systems of governance ((Meadowcroft 2009, Pelling 2011, Bulkeley and Tuts 2013, Chu et al 2017). This suggests that there is a 'need for more radical governance shifts than those observed empirically so far' (Wolfram et al 2019: 2). Transformative processes intentionally disrupt existing policy structures and often produce contestation and conflict (Meadowcroft 2009, Aylett 2013a, Eriksen et al 2015).

5.3 Situated and contextual

While the debates about climate change tend to be at the national and international scales, cities have been targeted as key arenas for both mitigation and adaptation since the 1990s (Bulkeley 2010, Castán Broto 2017, Wolfram et al 2019). Climate risks are context-dependent and cities provide a manageable scale to diagnose problems and develop solutions. Anguelovski and Carmin (2011: 169) describe these local approaches to climate governance as 'the ways in which public, private, and civil society actors and institutions articulate climate goals, exercise influence and authority, and manage

urban climate planning and implementation processes.' Researchers have produced a plethora of urban adaptation case studies with context-specific findings and insights (see **Table 1**).

Table 5.1: Examples of Case Studies on Adaptation and Urban Governance

City/Region	Author(s)
Algiers, Algeria	Boughedir 2015
Bhubaneswar, India	Chu 2016
Cancun, Mexico	Pelling 2011
Dar es Salaam, Tanzania	Shemdoe et al 2015
Durban, South Africa	Aylett 2010a, 2010b, 2013b, Carmin et al 2012, Leck and Simon 2013, Chu et al 2017
Da Nang, Vietnam	Du et al (2018)
South East Florida, USA	Vella et al 2016
Gujarat, India	Chu 2016
Indore, India	Chu et al 2017, Chu 2018
Lomma, Sweden	Wamsler 2017
Madrid, Spain	Olazabal et al 2018
Manchester, UK	Carter et al 2015
Maputo, Mozambique	Artur and Hilhorst 2012, Castán Broto et al 2015
Medellin, Colombia	Chu et al 2017
Munich, Germany	Wamsler 2017
Odisha, India	Walch, 2019
Portland, USA	Rutland and Aylett 2008, Aylett 2013a, 2013b
Quito, Ecuador	Anguelovski et al 2014, Chu et al 2016
Rotterdam, The Netherlands	Hölscher et al 2018
Santiago, Chile	Patterson and Huitema 2019
Surat, India	Anguelovski et al 2014, Chu et al 2016
Sydney, Australia	McGuirk et al 2016

Where climate mitigation efforts are often debated and enacted at the national and global scales, adaptation is most often a contextually specific phenomenon that reflects the local character of climate action (Anguelovski and Carmin 2011, Carmin et al 2012, Anguelovski et al 2014, Chu et al 2016, Castán Broto 2017). A common approach to adaptive urban climate governance involves transnational municipal networks (Bulkeley 2010, Bulkeley and Tuts 2013, Fünfgeld 2015, Bellinson and Chu 2019, Heikkinen et al 2019). Here, there is a focus on larger elite cities and the development of horizontal connections between municipal authorities based on cooperation, coordination, and mutual support (Bellinson and Chu 2019). However, other modes of adaptive urban climate governance are inward focusing and involve various configurations of local and regional stakeholders (Anguelovski and Carmin 2011, Anguelovski et al 2014, Castán Broto 2017). In both cases, 'climate adaptation is thus an archetypal strategic planning challenge because it requires bridging public and

private interests, local and extra-local jurisdictions, and short versus long-term development time-frames' (Chu et al 2017: 179).

5.4 Participation and collaboration

The local focus of adaptation actions results in a heightened emphasis on participatory and collaborative planning. Participation in urban planning was introduced in the 1970s in response to the largely technocratic planning approaches that were commonplace since the early twentieth century (Aylett 2013b). By the 1980s, governments had appropriated the notion of participation into an instrumental and bureaucratic exercise, where collecting public input is simply another institutional task for local governments. More recently, there has been increasing advocacy of 'co-' words such as co-production, co-creation, collaboration, and co-design to advocate for more interactive and emancipatory modes of participation (Ansell and Gash 2008, Newig and Fritsch 2009, O'Brien et al 2009, Renn and Schweizer 2009, Bason 2010, Bremer 2015, Wamsler and Raggers 2018). Here, there is a commitment to going beyond institutional participation to involve citizens as engaged and influential stakeholders (Aylett 2013a, Bulkeley and Castán Broto 2013, Wamsler 2017).

Participatory climate governance places a strong emphasis on inclusion of local actors who have the responsibility and capacity to act, results in the recasting of state-society alliances and new modes of interaction between the state and civil society (Archer et al 2014, Chu et al 2016, Moser and Ekstrom 2011, Castán Broto 2017, Chu 2018). In many cases, the state takes on a supporting role while civil society actors take the lead (Aylett 2013a). As Chu and colleagues (2016: 375) argue, 'Adaptation options are considered to be more effective if designed, implemented and monitored with engagement by those who have knowledge of the place'. The emphasis on local participation shifts the focus from a problem-centred approach to a community centred approach that is arguably more holistic and embraces the contextual specificities of climate adaptation (Bennett et al 2016).

Participation in climate adaptation governance is advantageous because it raises awareness, supports community self-reliance and capacity building, feeds into processes of collective learning, takes advantage of local knowledge, and has the potential to connect up with other issue such as public health or disaster planning (Anguelovski and Carmin 2011, Aylett 2013a, Chu et al 2017, Bellison and Chu 2019). Moreover, there is an increasing emphasis on justice and equity which is of particular relevance to low-income and neglected communities that often bear the brunt of climate change (Anguelovski and Carmin 2011, Chu et al 2016). Meanwhile governments benefit from more informed policymakers and improved policies that are easier to implement, transparency and accountability in government bodies, and increased legitimacy of the government as well as reduced public opposition (Aylett 2010b, Aylett 2013a). However, participatory climate governance also has potential disadvantages. Participation can lead to further consolidation of power by those who facilitate participatory processes and result in the further marginalisation of disempowered groups (Aylett 2013a). It can also reframe the local authority as a facilitator rather than protector of social welfare and effectively abdicate collective responsibilities to a dispersed group of disorganised stakeholders (Aylett 2013a, Baker and McGuirk 2019).

A critical element of participation is to scrutinise how it is performed as well as its intended outcomes. In most discussions around participation, there is an implicit understanding that consensus and compromise is the most desirable end goal. The alignment of interests around common objectives is assumed to be the most effective way to govern. However, some scholars note that conflict and dissensus can also be useful tools of participatory governance (Pløger 2004, Aylett 2010a, Aylett 2013a, Gualini 2015). As Aylett (2010a: 483) argues, 'both conflict and collaboration are legitimate and mutually re-enforcing forms of participation.' Social movements and civil society organisations provide insights on how conflict can be used as a generative tool for catalysing change. This broader perspective recognises consensus and conflict as two sides of the participatory model.

5.5 Entrepreneurship, innovation, and experimentation

In addition to participation, climate governance is increasingly characterised by activities that can be described entrepreneurial, innovative, and experimental modes of urban development (Anguelovski and Carmin 2011, Anguelovski *et al.* 2014). There is an understanding that creativity, strategic capacity, and small actions are a necessary component of adaptive urban climate governance (Bulkeley and Castán Broto 2013). The focus on entrepreneurial governance involves both strategic thinking by the state as well as looseness for broad coalitions of actors to shape and contribute to a collective agenda. As Swilling and Hajer (2017: 4) note:

> *The clearest indicator of entrepreneurial urban governance is when city policy makers (at political or managerial level or both) form open coalitions/partnerships with a range of knowledge institutions, public agencies, social enterprises, civil society formations, creative industries and entrepreneurial businesses (usually locally rooted) to address a particular challenge which, in turn, tens to create the basis for a more durable alliance to go on to tackle wider challenges.*

The drive for entrepreneurial urban governance is closely connected to notions of innovation and experimentation (Anguelovski and Carmin 2011, Karvonen and van Heur 2014, Evans et al 2016, Turnheim et al 2018). Experimentation can be understood as a process of innovation to create alternative futures that can address imminent climate realities (Bulkeley and Castan Broto 2013, Castán Broto 2013, Castán Broto 2017). There is an embrace of the non-routine (Healey 2004) and a desire to develop radically new configurations of governance and action that can address the challenges of climate adaptation (Anguelovski and Carmin 2011). As Chu (2016: 440) argues, 'experiments seek to transform entrenched government practices and generate new governance capacities.' These experiments are frequently opportunistic and incremental with the hope that 'a thousand flowers bloom' through a wide range of discrete interventions (Evans and Karvonen 2011, Aylett 2013b, Bulkeley and Castán Broto 2013, Boyd and Juhola 2018). This results in 'multiple and sometimes unlikely places through which governing is conducted and has fundamental implications on how we know and govern the city' (Bulkeley and Castán Broto 2013: 362).

Moreover, the spatial aspects of experiments are important to consider. Experiments are frequently situated in innovation zones, urban laboratories, urban living laboratories, and testbeds (Bulkeley and Castán Broto 2013, Castán Broto 2013, Karvonen and van Heur 2014, Castán Broto 2017, Chu 2016, Evans et al 2016). These sites provide tangible platforms to demonstrate the efficacy and contextual

fit of the experiments. All of these efforts involve an 'intentional and proactive process that involves the generation, practical adoption, and spread of new and creative ideas which aim to produce a qualitative change in a specific context' (Bellinson and Chu 2019). Experiments are often created through participation and collaborative modes of governance to co-produce climate adaptation solutions (Bulkeley and Castán Broto 2013, Patterson and Huiteema 2019).

Perhaps the most important aspect of experimentation for climate adaptation is the processes of 'learning by doing' that are developed (Eriksen et al 2015, Swilling and Hajer 2017, Bellinson and Chu 2019). Experiments provide a space for different actors to come together and focus on open-ended and recursive modes of trial and error (Bulkeley and Castán Broto 2013, Castán Broto 2017). Experimenters have the opportunity to flexibly frame adaptation objectives, undertake trials to test potential solutions and then evaluate their outcomes (Castán Broto 2017, Chu 2018). They tend to be short term and multiple rather than emphasising best practices and standardised approaches (Castán Broto 2017). Wolfram and colleagues (2019: 3) argue that governance involves 'situated learning processes to modify previously established modes of governance in terms of polity, politics and/or policy.' These collective or social learning actions involve processes of co-production that are transdisciplinary and are informed by multiple perspectives (Olazabal et al 2018). Such processes are intended to provide clarity and direction for climate adaptation approaches and to inform decision-making processes (Pelling 2011). Inevitably, they also raise key questions about who is involved in learning processes, how these processes are sustained over time, and how they can be scaled up and rolled out to other locales (Karvonen et al 2014, Chu 2016, Wolfram et al 2019). However, it is increasingly common to use experiments to catalyse new modes of governance related to climate adaptation (Bulkeley et al 2015, Frantzeskaki et al 2016, Patterson and Huiteema 2019)

Key points from the above are summarized in Table xxx:

Table 5.2: adaptive governance: key definitions and citations

ADAPTIVE GOVERNANCE ISSUES	*TYPICAL DEFINITIONS*	*KEY CITATIONS*
Governance	a distributed activity "involving a multitude of variegated public and private actors and relationships that operate through multiscalar and multiactor networks"	Rosenthal and Newman 2019: 1438
Adaptive climate governance	"decision-making systems comprising formal and informal institutions and social networks that are able to adapt in the face of uncertainty"	Boyd and Juhola 2015: 1235
Collaborative Governance	"A governing arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs or assets."	Ansell and Gash 2008: 544
Multi-level governance	Two types of governance approaches: Type I as the "dispersion of authority to a limited number of non-overlapping jurisdictions at a limited number of levels. Jurisdictions in this system of governance tend to bundle authority in quite large packages; they are usually non-overlapping; and they are relatively stable." Type II "pictures a complex, fluid, patchwork of innumerable, overlapping jurisdictions. These jurisdictions are likely to have extremely fungible competencies, which can be spliced apart into functionally specific jurisdictions; they are often overlapping; and they tend to be lean and flexible- they come and go as demands for governance change."	Hooghe and Marks 2001: 5
Urban Climate Governance	"the ways in which public, private, and civil society actors and institutions articulate climate goals, exercise influence and authority, and manage urban climate planning and implementation processes" where "central to the institutionalization of urban climate action is the development of regulations, policies, codes, and support programs"	Anguelovski and Carmin 2011: 169-170
Adaptive capacity	"the ability to respond to challenges through learning, managing risk and impacts, and developing new knowledge and devising effective approaches"	Marshall et al 2010: 5
Deliberate Transforma-tions	"The shifts called for may include a combination of technological innovations, institutional reforms, behavioural shifts and cultural changes; they often involve the questioning of values, the challenging of assumptions, and the capacity to closely examine fixed beliefs, identities and stereotypes … to be successful they typically require changes to entrenched systems maintained and protected by powerful interests."	O'Brien 2012: 670-671

Public participation	"securing the active involvement of a broad range of stakeholders in decision-making and action"	Few et al 2007: 47
Climate governance experiments	"primarily engaged in *explicitly* making *rules* that shape how communities respond to climate change … initiatives with a conscious intention to create/shape/alter behavior by setting up rules (broadly conceived as including principles, norms, standards, and practices) for a community of implementers (whoever and whatever they may be) to follow"	Hoffman 2011: 17

5.6 Adaptive governance as cognitive systems

(JR)

This section covers some remaining key issues: formal governance of the peri-urban as part of a FUA: informality and corruption in land and development: peri-urban strategic policy intelligence, and the emergence of collective intelligence in adaptive governance.

5.6.1 Peri-urban and strategic governance issues

The peri-urban raises extra challenges for governance, with typical mismatches between governance units and functional areas or ecological zones: or in general, between functions and territories (Friedman and Weaver 1986). A common syndrome is 'under-bounding', where the affluent migrate outwards to a low-tax peri-urban hinterland, using the big-city services, but leaving a shrinking inner municipality with the burden of poverty and decline (Briffault 1996). Another syndrome has been termed 'under-structuring', where an industrial city expands into a post-industrial agglomeration, with disruptive change across the fringes and in-between spaces, emerging as a peri-urban 'anti-city' or 'carceral city' of expressways, malls and enclaves (Soja 2001).

There are many rational arguments for strategic metropolitan or city-region governance, but there are challenges in defining the peri-urban hinterland, and balancing formal and collaborative types of governance (Aalbers and Eckerberg 2013). These challenges are amplified in the extreme case of governing coastal megacities and their peri-urban areas (Pelling and Blackburn 2013)

5.6.2 Informality & corruption.

Much of the peri-urban development around the world is informal, either by low income squatters and slum dwellers, or by high income real estate entrepreneurs, or by organized crime gangs who use peri-urban real estate for money laundering. There is also a long history of the urban fringes and interstitial spaces as natural locations for grey or black economies, illegal dumping, trafficking and forced labour (Clay 2004: Farley and Roberts 2011).

Organized or endemic corruption is a scourge, estimated to cost at least ten times the global development bill of $100 billion, with rampant exploitation particularly of women and of migrant

workers. This is endemic not only in narco-dictatorships, but apparently democratic nations such as India or Brazil (Transparency International 2013). More recent anti-corruption campaigns are framed not only as regulation and enforcement, but as more nuanced behavioural and social issues (World Bank 2012). But progress is slow when whole sectors and social institutions are based on informality and corruption, and even the anti-corruption programs are quickly absorbed and co-opted (Andrews 2013: Lambsdorff 2007). Much of higher-income peri-urban development in Asia and Africa is funded by remittances, from migrant workers in countries such as Dubai, which then evade local taxes and regulations, taking advantage of legal pluralism or tribal 'customary' governance (Cobbinah and Amoako 2012).

The responses or 'coping' of informal slum-dwellers to environmental stress and climate change is now documented in Africa and Latin America (Stein-Heinemann 2016). While slum dwellers in many countries are taking steps towards some level of security, new kinds of informality are emerging, such as 'radical cities' experiments, in co-housing or cooperative models, and in peri-urban-rural food systems (McGuirk 2014). The *AirBnB* and *WeWork* online platforms can also be seen as a kind of digital informality, with the capacity to transform property ownership or rental systems, which then enable further levels of transience and multi-locality in peri-urban areas (Di Marino and Lapintie 2018).

5.6.3 Peri-urban strategic policy intelligence

The interactions of the peri-urban and climate risk / adaptation bring new challenges and opportunities to conventional forms of governance. In response, 'network governance' aims for social norms and collective action to emerge from social learning (Head 2008): and 'associational democracy' is a model for collaborations between groups and networks, citizens and state, or workers and management (Baccaro 2005: Hirst, 1994: Westall 2013).

With a frame of governance for collective management of systems, Operations Research was developed for a rational management of complexity and uncertainty (Ackoff 1973). Then the science of cybernetics (Greek for governance) began to explore the 'socio-cybernetics' of cooperative behaviour (Bookchin 2008): and then 'second order cybernetics', where the observer / learner is part of the system (von Foerster 2003).

With online platforms, social media and AI, new possibilities emerge for collaborative learning, strategic policy intelligence and horizon scanning, shifting from linear-style 'information' towards an open-source synergistic 'wisdom' (Duval 2010).

For the challenges of climate and ecosystems, long-standing concepts of environmental justice have emerged as political ecology and liberation ecology (Heynen et al 2006: Martinez-Alier 2002). Management of resources such as water supplies are at the very roots of governance, but the focus has shifted from local to global: 'ecological democracy' is a political concept, inclusive, participative and equitable, as suggested by Ostrom's 'institutional design' for management of the commons, or Hajer's environmental discourse analysis (Mitchell, 2006: Ostrom 2005: Hajer 2003). For cultural dimensions, 'deliberative democracy' addresses more complex open-ended questions with in-depth discussion (Fishkin 2009: Gutmann and Thompson 2004). This aims for citizen participation and community budgeting with 'direct democracy' to mobilize the wider social intelligence, as in the well-

known 'ladder of participation' (Arnstein 1969: Hester 2006). At each fractal level the complexity of the 'collective governance intelligence' should aim to match the complexity of the problem, as in the 'law of requisite variety' (Ashby 1956: Hoverstadt 2008). This helps to guide the many methods and tools for elicitation, participation, visioning, social learning, consensus building, evaluation and socio-cybernetic governance (Geyer and Rihani 2010: Noveck 2015).

5.6.4 Collective intelligence in adaptive governance

Framing adaptive governance as learning loops on complex problems and responses, the multi-loop learning approach sees policy as learning about the problems, the responses, and the results by evaluation (Argyris and Schon 1996). Their notion of single and double loop learning can then be generalized in terms of co-evolutionary complexity as three *Modes* of system organization and response (Ravetz and Miles 2016: Ravetz et al 2020):

a) For direct functional problems (e.g. where to put 5000 houses) a single loop of bounded policy and learning (*Mode-I*).
b) For evolutionary type problems (e.g. 'how to revive housing markets'), a 'smart' or strategic double loop (*Mode-II*) is more effective.
c) And for deeper challenges (e.g. 'how to grow liveable communities'), there's a multi-loop (*Mode-III*), which enables and enabled by a form of *collective political intelligence*.

For each mode there are suitable structures and processes*:* gathering information in Mode I, the 'wisdom of crowds' in mass voting and decision-making can be effective (Surowiecki 2005). But this model is also vulnerable to hijack or co-option: in the UK for instance, regional partnership governance was disbanded in 2010 and replaced with slogans on 'localism', while in reality, the poorest municipalities were starved of resources, while public services were shifted away from local 'hollow states' and into quasi-private consortiums (Mair 2013).

This points towards an emerging '*collective democratic intelligence'*, framed by some as a 'collective wisdom' (Landemore 2013). One major experiment in collective intelligence was the London Collaborative (Mulgan 2016), which combined technical information with public deliberation. But while the digital revolution is now starting to transform (in some ways) government with big data and AI, these are often overlaid on historic structures (NESTA 2018: Tapscott and Williams 2007). There are various schema for mapping the complexity of power and governance institutions. With the multi-level approach of Green (2016): *'Power with'* emerges by synergies and collaboration: *'power within'* is about confidence and vision: *'power to do'* is the capacity for joint action or 'co-production': which leaves the conventional *'power over'* for coercion and control of others. A fifth dimension of power can then be added, the *'power of thought'* for collective learning, thinking and creating (Ravetz 2020).

6 Global issues & adaptive pathways

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6.1.1 The emerging global peri-cene

From the draft reviews, it appears there are overarching issues and challenges to be addressed, at the edge of the mainstream consensus. This is put here as four propositions, based on emerging literature, to be challenged and debated.

- ***Planetary peri-urbanization*** – i.e. the 'peri-cene': this looks at the global level of peri-urban expansion as greater than that of urban areas alone , and showing features of an inter-connected system
- ***Peri-urban transformations***: related to the planetary view, this looks at or beyond the edges of current concepts (e.g. beyond current functional framing of 'urban' as a social and economic metabolism, towards for example, hyper-virtual realities, or hyper-connected lifestyles beyond urban vs rural.
- ***Climatic tipping points***: some recent literature observes arctic melting and similar changes occurring much faster than model predictions. Implications for the peri-urban is that much larger areas may have to relocate or fundamentally restructure, much sooner than previous scenario foresights
- ***Hot-spots, dry & wet-spots:*** the combination of the above produces 'hotspots' (literally), where large areas may become uninhabitable within this century (e.g. temperatures of over 60 degrees in the Gulf states, or the current 'zero cities' without water, or flooding of entire megacities in coastal SE Asia.

A fifth proposition for ***adaptive pathways*** then makes the link between such challenges, the societal responses, and practical applications in road-maps and strategic thinking / planning.

6.1.2 Planetary peri-urbanization – i.e. the 'Peri-cene':

Arguably, the planet has not only entered the Anthropocene, but also a '***Peri-cene'*****:** a global human-environment pattern and system shaped by peri-urbanization (Moore 2016). Around the world the peri-urban displays many characteristics: global hubs and local enclaves, sprawl and disorder, disruption of communities and livelihoods, and in particular, growing climate risks and ecological disruption. Peri-urbanisation is both a material process of land-use change and impact, and a human process of social, economic, political, and cultural transitions: whether informal or planned, intensive or extensive, the peri-urban is critical to the provision of urban food, energy and water.

On current trends, the proportion of slums and/or informal settlements could increase to over half of the world's urban population by 2030 (Neuwirth, 2005). The form of urban agglomerations is also changing: the former hard edges of urban built form are shifting to a more fragmented and diffused pattern (Angel, Sheppard & Civco, 2005). So it is quite plausible that more than half of the world's

urban dwellers will be in quasi-temporary shacks, lacking fixed systems such as water, sanitation and electricity, in a peri-urban sprawl somewhere between rural and urban (Webster & Lai 2004).

Behind the trends, we can look at the 'world urban system', with implications for urban ESS. There is much study of the urban hierarchy, with countless league tables for size, GDP, competitiveness and so on. At the top are the 'alpha' global cities including London, New York and Tokyo, based on global connections in finance, business, professions, media / cultural power and 'cognitive capital' (Sassen, 1994: Scott, 2000). This kind of ranking is different to that of pure size, where the megacities of Africa and Asia are rapidly overtaking older cities such as London. More relevant to urban ESS is the national development profile, which correlates closely with the urban environmental transition above (McGranahan, 2006):

- lower income countries: often rapid and/or unplanned urban growth, combined with rural out-migration. There is a focus on primary production, with close connections to urban-rural ESS and physical resources: often with negative local effects on air, water and sanitation, ground and soil quality.
- middle income (industrializing): more rapid urban growth, with some areas of decline and restructuring, with regional demands on water, energy, minerals etc. In terms of production there is a towards secondary and advanced industrial sectors, with expanding urban infrastructure; again there are negative local effects on air, water, ground and soil quality, however growth in prosperity can (potentially) enable cleaner production and rising standards for workers and consumers.
- higher income countries: as seen in the UK, there is a generally slower urban growth and/or decline and restructuring: complex patterns of counter-urbanization and re-urbanization. In terms of production, the shift to tertiary services, knowledge based occupations and intensive consumption activities, brings new kinds of ESS interactions: environmental impacts and hazards are generally displaced to other parts of the world, or (in the case of climate change), future generations.

However these categories are changing very rapidly. The trajectory from pre- to post-industrial cities which in the UK took several hundred years, is accelerated into a very few years in the new megacities of Asia, Africa and Latin America.

6.1.3 Global urban-ecological interactions:

One starting point is the study of global ecological zones and urban locations, with implications for ESS distribution, trends, risks and opportunities. Here the primary reference point is the MEA (Millennium Ecosystems Assessment, 2004: Chapter 27 on Urban Systems):

- coastal zone: around the world this is the primary zone of urbanization, with a quarter of the world's population: two thirds of the population in the coastal zone is urban. At the same time, the coastal zone cities and megacities are generally the most vulnerable to natural hazards and climate change-induced hazards: with storm, flood, earthquake, sea-level rise and land instability. Coastal megacities in developing countries also tend to have low incomes and levels of development, with low capacity in governance and civil institutions.
- 'cultivated' zones contain a total urban population of nearly 2 billion:
- 'Dryland' zones with an urban population of nearly 1 billion are particularly vulnerable to climate change heat and drought, with growing water shortages and soil erosion:

- Forest and inland water locations are more vulnerable to fluvial flooding, landslip, forest fires and other hazards.
- mountain locations are also vulnerable to many environmental problems, including air and water quality.

In each of these zones there are complex interactions between urban, peri-urban and rural areas, in terms of migration and labour, agriculture and forestry, energy and water and so on. In many cases rapid urbanization is changing or disrupting these interactions: but meanwhile throwing up new opportunities and resources, for example for peri-urban agriculture for local markets.

Recent modeling studies have explored in detail global patterns of urbanization, and their impacts on biodiversity (Seto et al, 2012: Güneralp et al, 2013). The overall outlook is challenging: "Urban land-cover change threatens biodiversity and affects ecosystem productivity through loss of habitat, biomass, and carbon storage.... If current trends in population density continue and all areas with high probabilities of urban expansion undergo change, then by 2030, urban land cover will increase by 1.2 million km^2, nearly tripling the global urban land area circa 2000. This increase would result in considerable loss of habitats in key biodiversity hotspots... Although urbanization is often considered a local issue, the aggregate global impacts of projected urban expansion will require significant policy changes to affect future growth trajectories to minimize global biodiversity and vegetation carbon losses." (Seto et al, 2012).

6.1.4 Emerging forms of peri-urban and eco-transformation

Looking ahead: there is higher certainty on continuing income growth from lower to higher levels of development and infrastructure. On current trends there would be continuing displacement of environment impact and resource levels, from local-regional to global levels. However the possibility of reverse development is very real. This includes the experience of the former USSR republics: rapid industrial fallout and shrinkage as seen in Detroit or Leipzig: or geo-political conflict which destroys major urban areas, as seen in the Middle East. Ironically such de-development can be favourable to ecosystems which colonize vacant or derelict land, and new forms of habitat in empty and decaying buildings.

In contrast some new urban types are emerging with major implications for urban eco-systems services ('ESS'). A techo-economic development agenda sees a new generation of decentralized edge cities, the *aerotropolis* model, and the carceral-enclave urbanism of 'post-metropolis' (Soja, 2001: Kasarda and Lindsay, 2011). The extreme cases are seen in cities such as Dubai or Qatar, systems of migrants and urban spectacles, where hostile climates are overcome with massive energy and technology inputs (Krane, 2009: Ravetz, 2013). The role of urban ESS is then very different to the norm, being highly engineered and contained, and dependent on artificial structures and micro-climates. Another track sees an intentional sustainability and ESS agenda, which can take the form of 'smart', digital, integrated forms of energy, water and other infrastructure: as seen critically in Masdar or Songdo (Cugurullo, 2013). There is a parallel but opposite direction towards a low-tech, decentralized, communitarian kind of vision, as seen in the international movements for ecological Green Belts, agro-ecology and urban agriculture. Work in progress on urban futures in Finland has explored new paradigms in 'post-urbanity', new kinds of systems order and logic, beyond that of

present-day knowledge (see www.bemine.fi/ . Each post-urbanity has a primary 'dynamic' (technology, society, etc), and suggests an 'urban agenda', framed by questions, contradictions and oppositions, with strong implications for the peri-urban-climate agenda.

6.1.5 Climate tipping points and implications for the peri-urban:

Since the IPCC AR5, there is recent evidence that the rate of climate change is far greater than the projections: e.g. arctic melting, sea level rise, tropical storms. The current trajectory of INDs is pointing towards 4 degrees (Anderson & Bows 2018). The possibility of major tipping points is growing as we exceed 'planetary boundaries' (Rockstrom et al 2016: Lenton et al 2018).

The literature on tipping points, system catastrophes and long tails, highlights the dilemma: scientific knowledge proceeds cautiously by consensus, but tipping points / wild cards by their nature, cut across established fields & professions. This is now emerging in the debate on the conservatism of the IPCC (Pielke 2014). In practical terms, peri-urban areas and remote areas with rapid modernization show many features of extreme 'deeper threat multipliers' (WBGU 2007), where climate change is one among many factors, which combine to produce the dynamics of rapid systemic change. (Ravetz 2011). Key implications for the peri-urban could include:

- Relocation of entire cities (e.g. Jakarta may be the first)
- Water tipping points – drought / flood / sea level – with new agenda for the peri-urban as urban hinterland
- Food tipping points - major disruption to global food systems, with new agenda for peri-urban
- Social tipping points - climate migration pressure, particularly within larger countries, with new agenda for peri-urban development (large scale resettlements or refugee camps)

According to Fischer et al (2018): *"Future global warming may eventually be twice as warm as projected by climate models and sea levels may rise six metres or more even if the world meets the 2°C target'.* The research also revealed how large areas of the polar ice caps could collapse, significant changes to ecosystems could see the Sahara Desert become green, and the edges of tropical forests turn into fire dominated savanna.

6.1.6 Adaptive pathways

An ***adaptive pathway*** is a general approach to decision making under deep uncertainty, with multiple time steps, multiple stakeholders, multiple values and frames, and multiple conflicts (Haasnoot et al 2019). An adaptive pathway can be framed as including 'adaptive governance', along with adaptive business, technology, lifestyles etc: (conversely, a wider concept of governance as a generic collective intention could be framed as including an adaptive pathway.)

In parallel the ***'transition pathway'*** concept has emerged as a useful way to understand systemic change and evolution, particularly for technology / infrastructure systems such as energy or transport, and the climate mitigation agenda. Some key concepts are also relevant to the Peri-cene:

The Multi-Level Perspective, which looks for 'niches, regimes and landscapes' at different levels of systems, sub-systems and super-systems, helps to define local (niche) versus generic (landscape) changes or actions (Geels 2005). 'Transformative innovation' takes this further towards intentional systems change, by comparing mainstream R&D, systems of innovation and transformative change (Schot & Steinmueller 2018). 'Sustainability transitions pathways' highlight and address the challenges of governance and participation, in the situation of conflicting worldviews and objectives (Turnheim et al 2015).

For the Peri-cene approach, a multi-level ***'synergistic pathways'*** approach is proposed. This can help to integrate the above, respond to the complexity of both peri-urban and climate systems, and provide a practical mapping of ways forward. A synergistic pathway is defined as 'a process of learning and collaboration between multiple actors, based on the synergies between multiple values and rationalities', e.g. economic / ecological, or political / cultural (Ravetz 2020:46). Different levels of pathways can be mapped:

- *Mode-I* functional pathways focus more on technical issues and analysis: for instance, peri-urban flood management can focus on building physical defences.
- *Mode-II* evolutionary or 'smart' pathways are more about transition by evolution, innovation, incentives and competition: here the flood management is framed to maximize market values (with typical side-effects of social inequality, displacement of impacts etc).
- *Mode-III* co-evolutionary or 'synergistic pathways' explore the potential transformation via the qualities of collective intelligence. The Peri-cene *synergistic pathways* look for *deeper* and *wider* integration of policies, technologies, markets, social networks and cultural waves.

Such qualities of collective intelligence are a long story, with just a brief sketch here (Ravetz 2020). One foundation is systems thinking, the concept that the whole is greater than the parts, with patterns of feedback and response between them (Meadows 2008). Systems can then respond to change, as in 'adaptive systems', or set intentional goals for systems resilience or systems sustainability (Clayton & Radcliffe 1996: Beer 1966). This leads to the notion of 'complex adaptive systems' (Folke et al 2002; Waltner-Toews et al 2009), and then with combinations of material and cognitive factors, towards 'conscious systems', Mode II learning and 'second-order cybernetics' (Argyris & Schön 1996; Yang & Shan 2008). There are many applications of collective intelligence thinking, such as the co-evolution of human institutions (Corning 1995), the interaction of digital with human systems (Mulgan 2016), and the emerging concepts of an 'Urban 3.0' paradigm (Cohen 2012).

Such concepts are useful to understand the cognitive system dynamics which drive peri-urban change, which have been framed as an 'anti-city-region', a system space of disorder, disruption and dis-connection (Ravetz 2020: Rauws & de Roo 2011). Responses to problems of such 'deeper complexity' go beyond quantitative modelling methods, and call for a more synergistic approach to both analysis and synthesis (see the D1-2 Framework report for further discussion).

7 Conclusions & implications

This brief review shows some implications for the wide-ranging Peri-cene research agenda. The various components of the framework help to structure the key issues, for spatial, environmental, governance and global issues.

Spatial layers, parameters and dynamics:

- Questions on land-use density and urban contiguity help to define the use of GHSL data as a global resource for all Peri-cene partners;
- The challenges of edge cities and rural-urban interfaces show up the gaps in knowledge on peri-urban climate risk.
- The problem of sprawl, disorder and disruption of ecosystems and social systems, each point to the exposure and vulnerability of affected populations.

Functional layers, parameters and dynamics.

- The economic dynamics of real estate are complex and generally outside of standard datasets on global real estate values. Local case studies will show the comparisons between different types around the world.
- Similar applies to employment, labour markets and livelihoods. The effects of peri-urbanization on bypassing livelihoods, and on extended but precarious labour markets, can be directly relevant to the climate risk exposure and adaptive capacity.
- Transport, energy and water infrastructure, and local-regional food markets, are all strongly related to the peri-urban, and all are highly exposed to climate hazards.

Social-cultural layers, parameters and dynamics:

- The socio-cultural 'pull' factors of high-income peri-urbanization, include distance from the city, attraction to ecosystems amenities, and high mobility lifestyles. Each of these are potentially highly vulnerable to climate change hazard and exposure.
- Socio-cultural 'push' factors of low income peri-urbanization, include slum resettlement, or displacement / gentrification of rural settlements and livelihoods, with low levels of infrastructure or role in governance systems for climate change adaptation.
- This helps to explain how in developed countries with high levels of material infrastructure, there are typically high levels of inequality and socio-economic polarization, which then increases the climate vulnerability and sensitivity of certain 'left-behind' populations.

8 Annex

8.1 Abbreviations

CO_2	Carbon dioxide
CBD	Central Business District
CSR	Corporate Social Responsibility
EC	European Commission
EU	European Union
FUR / FUA	Functional Urban Region / Area
GDP	Gross Domestic Product
ha	Hectare
hh	Household
HDI	Human Development Index
IOT	Internet of Things
IPCC	Inter-Governmental Panel for the Scientific Assessment of Climate Change
KIBS	Knowledge Intensive Business Services
LED	Local Economic Development
Manchester	(Shorthand for Greater Manchester and its wider hinterland / region)
MEA	Millennium Ecosystem Assessment
NGO	Non-governmental organization
OECD	Organization of Economic Cooperation and Development
pph	persons per hectare
RUI	Rural-urban interface
RUR	Rural-urban region
SDG	Sustainable Development Goals
STEEPC	Futures / foresight domains for analysis ('socio-technical-economic-ecological-political-cultural'), with many variations
WEF	World Economic Forum
WHO	World Health Organization
UN, UNEP etc	United Nations, UN Environment Program etc

8.2 Glossary of terms

8.2.1 Spatial review terms

PERI-URBAN CONCEPT	*TYPICAL DEFINITIONS*
CARCERAL CITY / POST-METROPOLIS:	…a new flexible, information-rich, postfordist economy; the globalization of capital, labor, and culture; and the complementary revolution in ICT….
EX-URBIA / EX-URBS : Counter-urbanization concepts:	[…] as a particular form of amenity-driven sprawl at times reaching into the global countryside with profound effects.
'NON-PLACE' Socio-cultural experience concepts:	a landscape of 'non-places': transient, artificial, anonymous and alienated
EDGE CITY	New urban development hubs with rapid decentralization of urban functions
GREEN BELT POLICIES	A *greenbelt* is a policy and land use zone designation used in land use planning to retain areas of largely undeveloped, wild, or agricultural land surrounding or neighboring urban areas.
ECOSYSTEMS SERVICES	'Ecosystem services can be defined as services provided by the natural environment that benefit people'.
'PERI-URBAN ZONE' *(*Residential density concept:	Discontinuous built development, containing settlements of less than 20,000, with an average density of at least 40 persons per km2 (averaged over 1km2 cells)
'RURAL-URBAN FRINGE' : Spatial gradient / interface concept:	' […] that zone of transition which begins with the edge of the fully built-up urban area and becomes progressively more rural whilst remaining a clear mix of urban and rural land uses and influences before giving away to the wider countryside'.
'URBAN SPRAWL' : as a system concept:	'unplanned incremental urban development, characterised by a low density mix of land uses on the urban fringe': 'Low density, scattered urban development, without systematic large scale or regional public land-use planning':
'URBAN SPRAWL' : as a spatial definition	'low values in one or more of eight measures: density, continuity, concentration, clustering, centrality, nuclearity, mix of uses, and proximity
FUNCTIONAL URBAN REGION / AREA :	'an urban core and the area around it that is economically integrated with the centre, e.g. the local labour market.
'AEROTROPOLIS'	Specialized / globalized transit hub: also applies to retail or leisure malls, business or science parks etc.
PERI-URBAN AREA: Urban-rural linkage concept:	Parts of a city that appear to be quite rural but are in reality strongly linked functionally to the city in its daily activities.
PERI-URBAN-ISATION PROCESS	a process in which rural areas located on the outskirts of established cities become more urban in character, in physical, economic, and social terms, often in piecemeal fashion.
URBAN FRINGE	… transition zone between the built-up area and the countryside… interface between the consolidated urban and rural regions: a zone of mixed land uses with competition between them.

TRANSPORT EFFECTS	Automobile dependency is the concept that some city layouts cause automobiles to be favoured over alternate forms of transportation, such as bicycles, public transit, and walking, in a reinforcing feedback loop

8.2.2 Climate risk review terms

CLIMATE ISSUES	***Example definitions***
Climate change risk	"the potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values."
Climate vulnerability	"characteristics of human or social-ecological systems exposed to hazardous climatic (droughts, floods, etc.) or non-climatic events and trends (increasing temperature, sea level rise)
Climate change adaptation	'process of adjustment by societies and natural systems to the actual or anticipated effects of climate change'
Climate change resilience	'the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation'

8.2.3 Adaptive governance terms

ADAPTIVE GOVERNANCE	*TYPICAL DEFINITIONS*
Governance	a distributed activity "involving a multitude of variegated public and private actors and relationships that operate through multiscalar and multiactor networks"
Adaptive climate governance	"decision-making systems comprising formal and informal institutions and social networks that are able to adapt in the face of uncertainty"
Collaborative Governance	"A governing arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs or assets."
Multi-level governance	Type I as the "dispersion of authority to a limited number of non-overlapping jurisdictions at a limited number of levels". Type II "pictures a complex, fluid, patchwork of innumerable, overlapping jurisdictions".
Urban Climate Governance	"the ways in which public, private, and civil society actors and institutions articulate climate goals, exercise influence and authority, and manage urban climate planning and implementation processes" where "central to the institutionalization of urban climate action is the development of regulations, policies, codes, and support programs"
Adaptive capacity	"the ability to respond to challenges through learning, managing risk and impacts, and developing new knowledge and devising effective approaches"
Deliberate Transforma-tions	"The shifts called for may include a combination of technological innovations, institutional reforms, behavioural shifts and cultural changes; they often involve the questioning of values, the challenging of assumptions, and the capacity to closely examine fixed beliefs, identities and stereotypes … to be successful they typically require changes to entrenched systems maintained and protected by powerful interests."
Public participation	"securing the active involvement of a broad range of stakeholders in decision-making and action"
Climate governance experiments	"primarily engaged in *explicitly* making *rules* that shape how communities respond to climate change … initiatives with a conscious intention to create/shape/alter behavior by setting up rules (broadly conceived as including principles, norms, standards, and practices) for a community of implementers (whoever and whatever they may be) to follow"

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