

Approaching Integrated Assessment of Climate Change Impacts on Urban Settlements

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Abstract: The interrelationships and interdependencies between humans and their environment are inherently complex and dynamic. Urban settlements are of particular complexity and interest because of their concentrated geographies, form and structure, material flows and cultural and population dynamics. The risk of climate change impacts imposes another level of complexity on such human-environment systems and being able to better understand such complexity is becoming more urgent. This paper describes the methodological approach and conceptual framework developed for the Integrated Assessment of Climate Change Impacts on Urban Settlements (IACCIUS) project, which the author hopes will enable that better understanding. The methodology incorporates a number of approaches that lend themselves to the analysis of complex, dynamic, multi-scale, cross-sectoral, long-term real world problems posed by climate change. In particular, it describes how key aspects of dynamical systems thinking, urban studies; risk, vulnerability, adaptive capacity and uncertainty approaches; climate science; policy processes; demography and geography; stakeholder participation; and reflexive and iterative practice are incorporated into an IACCIUS conceptual framework. This paper concludes with a brief presentation of the evolving conceptual framework.

1. Introduction

Eighty percent of the Australian population lives in towns or cities. Apart from climate change, the pressures experienced by these settlements include risks from natural hazards such as fire and cyclones, rapid population decline or growth, deteriorating infrastructure, congestion and pollution, social inequities, stretched local government capacities and increased water and energy demands. These pressures are exacerbated by impacts from global, regional and local level changes in the climate. While increased temperatures, decreased rainfall and sea level rise are common to many places, some changes have and will vary from locale to locale. For example, in one place it might include an increased risk of the incidence of bushfires and diminishing water security, whereas in another place it might include an increased risk of more intense cyclones and debilitating daytime humidity. It is now widely accepted that global climate change 'is very likely due to the observed increase in anthropogenic greenhouse gas concentrations' (IPCC, 2007, p. 8) and that both mitigation of greenhouse gases and adaptation by human and natural systems are two necessary responses to this worrying trend (IPCC, 2001; Pittock, 2003). Adaptation is generally understood as the:

Adjustment in natural or human systems in response to actual or expected climatic changes or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory or reactive adaptation, private or public adaptation, and autonomous or planned adaptation.

(Pittock, 2003, p. 191)

In tightly coupled human-environment systems this might involve changing public or private policy to take into account actual or possible changes in the climate. For individuals, it might mean changing daily behavior, such as through reducing consumption of water and energy, so as to contribute to both the mitigation effort and to adapt to felt climatic changes. In sum, causes of anthropogenic climate change are deeply embedded in patterns of production and consumption, settlement and governance and the impacts of climate change are widely distributed across sectors and places and there is a strong connectivity both across and within categories of causes and impacts. In order to adopt proactive adaptive responses in urban settlements, the actual or possible impacts of, or vulnerabilities to, climate change needs to be better understood. Integrative approaches that enable assessment of the complex relationship between non-climate urban processes and local level climatic changes are therefore needed. Such integrative approaches should bring together environmental, social, economic, cultural, political and other factors, as well as research, policy and stakeholder communities.

In order to do this, this paper proposes a methodological approach and associated conceptual framework developed by the integrated assessment of climate change impacts on urban settlements (IACCIUS) project. Based on interest in the IACCIUS project, five small to medium sized case study urban settlements were selected to work in a participatory way to develop the approach. These include Canberra, Queanbeyan, Darwin, Bendigo and Cooma. The author hopes that the practical application of the IACCIUS approach, to be presented in a subsequent paper, will provide a basis for

further refining the IA approach for other urban settlements across Australia and possibly overseas. To set the context for this paper, a brief history of 'integrated assessment' (IA) is first presented.

2. History of Integrated Assessment

In the 1980s and early 1990s IA emerged as an approach to assess global environmental change and global climate change. The IA approach typically produced an integrated assessment model that was based on conventional quantitative scientific approaches to problem solving (Risbey *et al.*, 1996; Rothman and Robinson, 1997). These approaches were considered to be useful for providing insights, projections and even forecasts of the future world. They were, however, promptly criticized due to their bias towards inclusion of phenomena or variables that were considered not only measurable but also quantitatively modellable, such as through probabilistic risk analysis, to the exclusion of more intangible factors such as institutional settings or social perception and change. They were also criticized for not taking into account the complex, dynamic, adaptive relationships between the social, cultural, political and biophysical aspects of the human-environment system (Rothman and Robinson, 1997).

In response, various researchers and organisations have attempted to develop methodological and conceptual frameworks that take into account this complex relationship. Some of these include Jakeman and Letcher's integrated assessment and modelling approach to catchment management (2003); Jones' environmental risk assessment and management framework for climate change impact assessments (2001); the Millennium Ecosystem Assessment framework for ecosystems and human well-being (2003); and the Australian Greenhouse Office's climate change impacts and risk management guide (2006) (see Hutchinson *et al.*, 2006 for a review of these, and other, approaches). These approaches attempt to respond to 'the change in policy and research agendas from compartmentalized treatment of distinct sectors and issues, to the broader and more integrated agenda of sustainable development' (Hutchinson *et al.*, 2006, p. 24). The author has noticed that despite their broader approach, however, there are a number of limitations to these frameworks. In particular, they have tended to focus on rural systems and natural resource management. In addition, while they attempt to move away from conventional quantitative scientific methods, they continue to rely heavily on measurable quantitative data and probabilistic methods as the central analysis tool. For this reason they are not directly transferable to an integrated assessment of climate change impacts that focuses on urban settlements characterized by complex social, cultural and biophysical interrelationships. For this reason the proposed approach has melded a number of approaches that can help to conduct a more holistic IA. The key approach employed by IACCIUS are discussed next followed by a brief discussion of what the (evolving) IACCIUS conceptual framework.

3. Key Approaches

The Integrated Assessment Society defines IA as 'the scientific "meta-discipline" that integrates knowledge about a problem domain and makes it available for societal learning and decision making processes...[it] engages stakeholders and scientists, often drawing these from many disciplines' (IAS, 2006). In addition to this, IACCIUS views IA not as one approach, but as an intent and a process with emerging underlying principles and processes. IA is undertaken within a range of methodological frameworks and within a wide range of places, scales and problem contexts. Because of this, IA does not 'solve' problems; rather, it provides better understanding of complex real world problems. With this understanding, the IACCIUS approach to IA draws on the following fields and research approaches: systems thinking; urban studies; risk, uncertainty and vulnerability approaches; human adaptation; climate science; policy processes; demography and spatial science; stakeholder participation; and reflexive and iterative research practice. When considered together these approaches allow for the selection of tools and methods that are relevant to a complex issue or problem.

3.1 Systems Thinking

Fundamental to systems thinking is to seek understanding of some aspect of the real world in terms of a 'whole', discernable from its parts (Checkland, 1981). The age-old phrase 'the whole is more than the sum of its parts' is commonly used to describe this concept. Typically the parts of the system 'interact to constrain each others' behaviour' (Newell and Wasson, 2002, p.4). This limits the range of behaviours of the system as a whole and gives rise to the system's 'emergent' properties. It also means that a system is dynamic in that it changes over time. To incorporate systems thinking into IA, four systems principles (adapted from Proust and Newell, 2006; Li, 2007; Newell, 2007; Newell *et al.*, 2007; and Proust *et al.*, 2007) need to be adopted:

1. Feedback effects are important drivers of climate change and hence of climate change impacts and vulnerability in urban systems. A *fixes-that-fail* systems archetype (adapted from Senge, 1990), depicted in Figure 1(a) and Figure 1(b), is an example of this.

- Any action taken in an urban system will produce a spectrum of outcomes, both intended and unintended. Long time delays are common and history is important. An example of this is depicted in Figure 1(c).
- An urban system cannot be optimised by optimising its parts one by one in isolation. This means that any number of parts or sub-systems can be identified, the boundaries of the urban system are those identified by the observers of the system, and the system must be considered as a 'whole', which is greater than the sum of its parts. In Figure 1(d), it is shown that, for example, the human behavioural parts of the system cannot be considered in isolation from the natural system processes.
- The analysis, design and management of urban systems require integrative approaches. This means that single disciplinary or sectoral approaches that consider an issue, such as hotter days, and design a single management approach to deal with that problem, are likely to overlook critical feedbacks and constraining relationships in the system (see Figure 1).

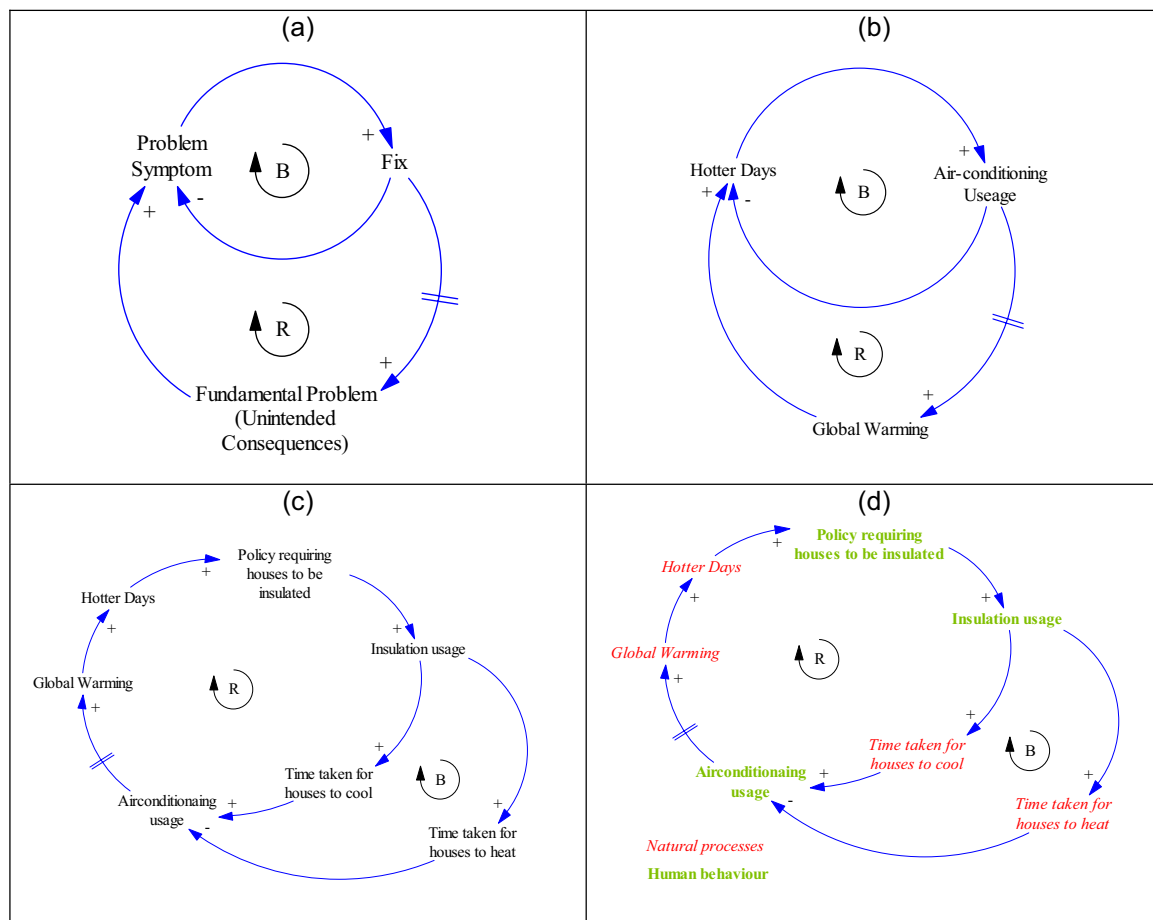


Figure 1. Feedback Effects: A Fixes-that-Fail Global Warming Example

3.2 Urban Studies

Most IAs have tended to focus on non-urban or rural environments (see e.g., Fischer *et al.*, 2005; Krol and Bronstert, 2007; Letcher *et al.*, 2007). However, the IACCIUS project is specifically concerned with urban settlements and draws on insights and approaches from the urban studies literature. In particular, the concepts of urban *structure*, *form* and *function*, and urban *metabolism* are central to the IACCIUS approach.

Urban structure refers to the spatial relationships between cities and their services and activities. That is, whether the activities are arranged in linear relationships and are highly centralised, or whether the city is structured as an interconnected set of nodes around which development is arranged (Troy, 2004). More specifically, structure concerns the skeletal make-up of a city such as its transport spines, growth corridors, water and sewerage infrastructure, and relationships between centres.

Urban form refers to the nature or density of development. All major Australian cities are essentially low density, especially in their residential areas. More recently, city centres are being developed to high density form (Troy, 2004). Form also concerns the aesthetic characteristics of the city. *Urban function* refers to what cities are expected to provide if they work or operate in a proper or particular way (Troy, 2004). For example, it is sometimes acknowledged that early planning decisions, such as structural centralization, can lead to settlement structures that are path dependent. This means that subsequent subdivisions and developments are limited and reinforced by the original structure, which can lead to inefficiencies in the way the city operates; that is, inefficient function (Troy, 2004). In Australia, the debate between the sustainability of certain urban structures, forms and functions is ongoing.

Urban metabolism refers to material and energy inputs needed to meet the demands of living and non-living components of urban systems, and waste and energy outputs (Boyden *et al.*, 1981b). The urban metabolism approach attempts to analyse the dynamic processes of the city as a whole. One of the first, and most renowned attempts to view a city in terms of a metabolism, was that of Boyden *et al.* (1981a) with their seminal urban metabolism study of Hong Kong. Central to their approach was the division between the 'total environment' and the 'human experience' of that environment. Boyden *et al.* distinguish the difference between the human settlement and its immediate hinterland, and sources of influences external to the settlement. Furthermore, they view every human as being a component part of the total environment who 'is affected by the properties of the system as a whole and also has the potential, however small, to influence this system' (Boyden *et al.*, 1981a, p. 93).

The metabolism model has since been further developed and modified by other urban researchers, such as Newton *et al.*'s (2001) modified version, the Extended Metabolism Model of Human Settlements. This model enables a representation and assessment of the built environment in terms of resources inputs; urban systems and processes, including change processes; liveability, which includes human well-being and environmental quality; and waste and emissions, including recycling and reuse. Yencken and Wilkinson (2000) have also drawn upon the urban metabolism model. They recognise that the strength of this model is its analytical framework, which allows for the comparison and measurement of the flows of energy, water, food and materials into settlements, and the waste outputs from them, over time; that is, a focus on the dynamics, or change processes, of the system.

The urban metabolism approach is most relevant to the IACCIUS methodology as it provides an underlying 'pre-tested' framework consistent with the systems thinking principles listed above. Urban metabolism considered in conjunction with urban structure, form, function and the systems thinking principles provide a powerful springboard from which to develop a robust approach to integrated assessment of climate change impacts on urban settlements. Since present and future impacts of climate change are a function of risk and uncertainty and may result in vulnerability, then these issues must also be included in the IACCIUS framework.

3.3 Risk, Vulnerability, Adaptive Capacity and Uncertainty

Different people, groups and societies view and define risk differently (Li, 2007). A quantitative approach to risk assumes measurability and would typically define risk as a being a measure of the magnitude of potential consequences of something happening (commonly undesirable) and the likelihood of those consequences occurring (Standards Australia, 2004). See, for example, Mastrandrea and Schneider (2004) who use a probabilistic risk framework to undertake an IA of dangerous climate change. Alternatively, disaster researchers define risk as the product of hazard and vulnerability (EMA, 1994; Granger and Johnson, 1994). In this case a hazard is considered to be something that is harmful or dangerous to a community (e.g. a climate change impact), and the magnitude and frequency is normally represented in probabilistic terms as related to the specific geographic area and specified time under consideration. Vulnerability in this case is considered to be the degree of loss of something of value (lives, livelihoods, buildings, land, recreational pursuits, quality of life, environmental quality) as a result of the impact of a hazard event. Conversely, a qualitative, constructivist approach to risk would typically define risk as a product of social, cultural and political processes (Douglas and Wildavsky, 1982; Lupton, 1999). Different frameworks for risk assessment and management are quite different depending on the way risk is viewed and defined.

Traditional quantitative approaches to risk typically follow an iterative 5-step risk management framework: 1) Establish the context, 2) Identify the risks, 3) Analyse the risks, 4) Evaluate the risks, and 5) Treat the risks, where risk assessment refers to steps 2), 3), and 4); see Standards Australia (2004). In the Standards Australia risk management framework, so called 'qualitative' assessments of risk retain the concept of measurability by using descriptive terms for measurement, such as 'very likely', 'likely', or 'unlikely' in place of numeric representations of risk. This quasi-qualitative approach

is very different to that described by Douglas and Wildavsky (1982), Lupton (1999) or Li (2007), although, it is quite useful in those instances where probabilistic estimates are required for decision making but numeric data are not available.

The Standards Australia risk management framework has been applied to climate change impacts by the Australian Greenhouse Office (AGO) (2006) in *Climate Change Impacts and Risk Management: A Guide for Business and Government*. This outlines a step-by-step approach to undertaking a preliminary risk assessment of climate change impacts based on globally recognised probabilistic climate change scenarios relevant to a certain region. The process is designed to be undertaken with an entity such as a business or government department, in a workshop format, which includes pre- and post-workshop collaboration and task setting. This approach is useful, though it assumes a linear view of risk, in assuming linearity between cause and effect, starting from the climate variable, to a change in the climate variable, to impacts, which then results in risk (see example in Figure 2).

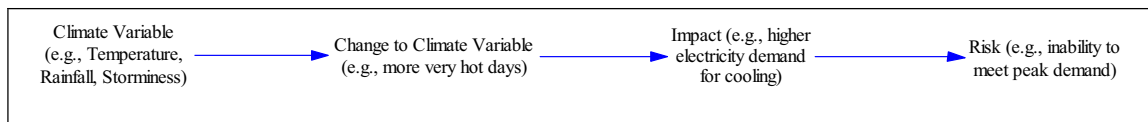


Figure 2. A Linear View of Risk of Climate Change Impacts
(Source: re-sketched from AGO, 2006, p. 16, Figure 4)

This risk management framework or way of thinking is then also applied to the concept of *vulnerability*, *adaptive capacity* and *uncertainty*. The AGO defines *vulnerability* as the 'extent to which a system or organisation can cope with the negative impacts of climate change, variability and extremes. It is a function of risk and adaptive capacity' (2006, p.71). *Adaptive capacity* is defined as the 'capacity of an organisation or system to moderate the risks of climate change, or to realise benefits, through changes in its characteristics or behaviour. Adaptive capacity can be an inherent property or it could have been developed as a result of previous policy, planning or design decisions of the organisation (AGO, 2006, p.70). Pittock defines uncertainty as the 'degree to which a value is unknown, expressed quantitatively...or qualitatively' (2003, p.196).

In the area of climate change research consideration or assessment of risk, vulnerability, adaptive capacity and uncertainty are no longer constrained by traditional views or approaches; rather they are now subject to more integrative approaches. In particular, conventional or traditional approaches to risk and vulnerability assessment, such as those presented by AGO (2006), have recently been succeeded by interdisciplinary and integrative frameworks that support sustainability goals and that utilise a systems thinking approach (Adger, 2006). For example, the Potsdam Institute for Climate Impacts Research applies a systems thinking approach with a particular focus on the interactions between humans and their environment. Similarly, in the IACCIUS project some of the elements of the risk management framework outlined by AGO (2006) is utilised, but the focus is more so on gaining a better, shared, 'systems' understanding of climate change impacts on the case study settlements.

The IACCIUS approach takes the concepts of risk, vulnerability, adaptive capacity and uncertainty further to account for the complex relationship that exists between human society and the environment. This relationship is typically non linear. As discussed earlier, complex human-environment problems like climate change involve dynamically changing human social and environmental systems commonly characterised by feedback relationships, long time frames and multiple system levels (Li, 2007). A linear, traditional view of risk then would be unsuitable for an integrated assessment of urban systems, which are complex, human-environment systems. This type of approach would integrate multiple views of risk and consider vulnerability using key systems concepts such as multiple systems levels, long time frames and the dynamics of change typical of complex human-environmental risk problems such as climate change impacts. This approach also allows for IACCIUS to accept quantitative, qualitative or other social constructionist approaches to risk and vulnerability. Furthermore, the IACCIUS approach caters for the incorporation of uncertainty into the assessment where uncertainty is not simply reducible to quantitative or qualitative values of the unknown. Rather, IACCIUS considers uncertainty as knowing the direction of change in a human-environment system but not knowing, with any precision or predictive capacity, the scale or probability of climate change impacts (Dovers, 2005, p.83). Especially in the case of large scale events, residual uncertainty is not well incorporated in traditional risk management approaches (Handmer and Dovers 2007). Dealing with such uncertainty is common in policy- or decision-making contexts, and through integrative frameworks communities can learn to better handle uncertainty rather than ignore or be

ignorant of it (Dovers, 2005). The non-linear systems view of risk depicted in Figure 1. above, is a good example of this.

3.4 Climate Science

The IACCIUS methodology involves integrating knowledge from multiple disciplines. Climate science is a more traditional physical science discipline that fundamentally informs integrated assessment of climate change impacts on urban settlements by providing insights into current trends and future projections of the climate at global, regional and local scales. The latter scale is most relevant as it focuses on specific settlements, rather than broad regions that evade local context. A key requirement for meaningful measures of both current and projected future climates is that they need to be made at local scales relevant to human response and to strategies for adaptive management. Surface climate depends closely on topography; in particular the impact of elevation on surface climate is around 100 times the impact of horizontal position. Thus climate statistics calculated across regions need to incorporate the influence of elevation, which can be obtained from observed standard climate mapping techniques (Hutchinson, 2004). Spatially detailed maps of projected future climate statistics can be most readily obtained by perturbing the source data underpinning maps of current climate according to the broad scale projections afforded by global climate models.

The key statistics used in the study of local scale climate include monthly, seasonal and annual means of primary climate variables, such as daily maximum temperature, daily minimum temperature and rainfall. These variables are primary determinants of plant growth and local water availability. Measures of climate variability are most usefully expressed in terms of observed or estimated frequencies of exceedance of particular thresholds. These thresholds include numbers of frost days and numbers of very hot days (heatwaves). These can have impacts on plant and crop growth, human health and energy needs for cooling and heating. Frequencies of exceedance can also be applied to standard indices based on climate, such as thermal stress indices for human comfort (Thompson and Perry, 1997). Rather than considered as external to the urban system, the IACCIUS methodology integrates these and any other locally relevant climate variables into any model or description of the urban system.

3.5 Policy Processes

As well as IA being an interdisciplinary approach in an academic sense, it is generally proposed that IA is integrated in the sense of it being an applied domain of research that informs policy making. In particular, IAs can connect to policy processes in two overarching ways: 1) through relevance to policy processes and 2) through exploration of policy processes in order to better understanding the urban system, its vulnerabilities and adaptive capacity. The connection to 1) has many dimensions, can take many forms, and should be closely considered in the context of a specific IA project and the policy questions to which a project relates. For IACCIUS, mapping the policy and institutional settings relevant to a specific context is an important requirement if the outcomes are to be policy relevant. That is, relevant to legal and administrative responsibilities, data flows and ownership, key policy and management processes of relevance to the identified sectors, impacts and issues. The IACCIUS approach involves gaining an understanding of this relevancy through engagement with policy agencies and members of the policy community in interactive workshops, meetings and means. It is not the goal of the IACCIUS approach to formulate policy, however, IACCIUS may influence policy to the extent that the insights and knowledge produced from the assessment are used by responsible authorities to inform decisions and actions during and post-project. It is for this reason that reflexive and iterative research practice, discussed below, is adopted by the IACCIUS project.

The connection of IA to 2) involves the current 'snapshot' of policy and institutional settings to be extended by exploration of the policy and institutional factors that have created the human-environment system interactions that now mediate and determine vulnerabilities and adaptive capacities. It is in the nature of policy and especially deeper institutional settings that their manifestations, such as land use patterns, settlement location, infrastructure, have considerable life spans. This means that the vulnerabilities to climate impacts and adaptive capacities to those impacts are likely products of past policy. Systems that tend to 'lock in' to one outcome once the initial conditions are set are said to be path dependent (Sterman, 2000). Sterman defines path dependency as a 'pattern of behavior in which small, random events early in the history of a system determine the ultimate end state, even when all end states are equally likely at the beginning' (Sterman, 2000, p.349). Thus, IA needs to incorporate a time depth in examining policy, to account for cause-effect chains, time lags and path dependencies. This is supported by a systems thinking approach.

3.6 Demography and Geography

Like climate science, demographic and geographic frameworks fundamentally inform integrated assessment of climate change impacts on urban settlements. The key focus in this respect is to gain a better understanding of how urban settlements' demographic and social characteristics and other geographic characteristics affect their vulnerability to climate change impacts. Demography is the study of population structure and change (Hinde, 1998). It informs our understanding of the size, composition and spatial distribution of populations, and of changes to these aspects through the operation of processes of fertility, mortality, marriage, migration and social mobility (Bogue, 1969). Demography also helps us understand the relationships between population and broader social, economic and environmental concerns. Geography is the study of place and space from both human and biophysical perspectives (Hubbard *et al.*, 2004). Spatial thinking is central to the geographic tradition and generally involves spatial analysis or mapping using Euclidean geometry, such as through geographic information systems (GIS). In contrast, thinking about place generally involves investigating people's lived experiences in a bounded space (Hubbard *et al.*, 2004).

To better understand interactions between climate change impacts, population and the spatial domain the IACCIUS approach employs demographic social profiling and associated spatial mapping techniques. While the contents of a demographic and social profile can vary according to the use for which it is intended, they may include: (i) population indicators, including population size, age structure, and gender balance; (ii) household indicators, such as household size, household type, and type of dwelling; (iii) economic indicators, such as patterns of income and employment; (iv) educational indicators, such as numbers of students and qualifications; (v) cultural indicators, such as places of birth and/or ancestry, languages spoken at home, and/or religion. Where possible, IACCIUS will draw from existing demographic and social profiles to help inform policy decisions. Consultation with participating stakeholders, a core activity of the IACCIUS project discussed below, is critical to gaining a fuller understanding of the demographic and social situation in the urban system. In the context of spatial mapping, IACCIUS incorporates hazard mapping, such as storm surge or fire risk zones, into the IA (see e.g., Stimson *et al.*, 2001). The differential vulnerability of sub-sets of the population is a particular focus. Although ideally the concept of 'place' is also incorporated into the IA, primary data collection methods normally used to access people's lived experiences, such as in-depth interviewing, is not within the scope of the IACCIUS project. In larger IA projects such methods would be invaluable to the IA process.

3.7 Stakeholder Participation

IA is typically defined as including a working relationship with 'stakeholders' otherwise termed a participatory approach to research. Like the connection to policy, this demands clarity and specificity about what such participation means, and what specific forms and degrees of participation are relevant to the project (Ross *et al.*, 2002; Dovers, 2005). Participation in research projects such as IACCIUS has two imperatives driving it: (i) to inform the analysis by inclusion of perspective, knowledge, and prior work held by members of agencies, local communities, etc that would otherwise be unavailable or difficult to obtain; and (ii) ensuring the relevance of the IA research to those responsible for using the resulting knowledge, through framing the questions, implementing the assessment and communicating the findings in an accessible and useful manner.

IACCIUS engages with selected members of the policy and professional/management communities who have relevant responsibilities within the jurisdictions being utilised as case studies. That is, public officials in local and territory/state agencies relevant to urban impacts of climate change. It is not considered that there is scope for engagement with place-based communities (the broader population of the settlements) at any meaningful level of detail, within the aims and time constraints of the project. Such wider engagement would be possible in large, longer term IA exercises.

The appropriate degree of participation varies both across and within IA projects. Close and ongoing engagement with some stakeholders may be appropriate; for example, where specific management issues are being dealt with, or community generated data are required. Alternatively, strategic involvement at key parts of the IA process may be appropriate; for example, in problem framing and later in communication of results. The interest levels and capacities of stakeholders is an important variable. Typically, stakeholders will participate in an IA as a voluntary activity, or at the margins of busy professional schedules. Expectations of the purpose and extent of participation need to be clearly defined and understood.

As with the degree of participation, the identity and number of stakeholders who participate will vary significantly from one IA project to the next. In some cases, close and sustained engagement with

local communities will be appropriate, whereas in other a smaller number of key representatives from management agencies will be the focus. The choice depends on the problems being investigated, the number of organisations, individuals or communities who are concerned with these problems, the methods employed, data required, and so on. The scope of the IACCIUS project involves investigating multiple issues across a number of settlements, which suggests engagement with key officials from relevant agencies, referred to as participating agencies, rather than extensive consultation with local communities. Furthermore, it is important that the relationship between an IA project and policy and management responsibilities are clearly understood by participating individuals and groups, since misunderstanding or wrong assumptions regarding the status of outcomes of an IA may cause later resentment. Expectations are discussed and agreed at project commencement and constantly reviewed and revised as necessary throughout the life of the project.

3.8 Reflexive and Iterative Research Practice

Reflexive research practice refers to the project team and the stakeholders being explicitly self critical and involves reflecting on methods and underlying epistemologies and methodologies of the approaches taken and how they might be integrated (Alvesson and Sköldbberg, 2000). Iterative research practice refers to the process of the integrated assessment as a learning process for all those involved and as the project proceeds new findings and things learned are incorporated into the project findings and elaborations (Layder, 1998). The IACCIUS methodology explicitly incorporates reflexive and iterative research practices, which involve the development of a lessons learned database for use over the life of the project and post project.

4. The Evolving IACCIUS Conceptual Framework

The range of approaches discussed above is drawn together here in an evolving or interim conceptual framework; see Figure 3. This is the key tool that the IACCIUS project is attempting to develop as a generic yet powerful means of thinking about complex human-environment 'urban' problems, where the nature of the problems demand integrated solutions. The conceptual framework is not to be interpreted as a model of any specific urban settlement, but as a means of organizing the kinds of parts and processes that might need to be considered in a specific situation. The framework should help to identify the most important and pressing questions. Once these are identified then the most appropriate methods for answering those questions can be considered. Although humans typically need to break off 'bite sized pieces' of complex situations in order to make them manageable, the framework is designed to remind us that these parts of the problem always have links to other areas. As the systems thinking approach reminds us, the overall performance of a system cannot be improved by trying to improve the performance of some part in isolation.

The sketch depicted in Figure 3 incorporates the above frameworks and draws on key components of Boyden *et al.* (1981b, pp. 90-92, Figures 4.1, 4.2 and 4.3) and Millennium Ecosystem Assessment (2003, p.37, Box 1.4). The notable aspects depicted explicitly in Figure 3 are: the concept of *scale* (local, regional, global, society, individuals); *urban characteristics* (e.g., water infrastructure, population, culture); *subsystems* (biophysical, human activity, modified physical and human biological, socio-cultural, individuals); *flow arrows* (e.g., inflows, outflows, emissions, energy, water); and *interaction and feedback arrows*. The notable aspects not depicted explicitly are the concept of *change* (e.g., change in climate, population, perceptions), which is a dynamic concept; *uncertainty*, which is ever-present and *time*, which is also a dynamic concept. Since these latter three concepts are difficult to sketch, optimal ways of depicting them are currently being developed and will be tested via the IACCIUS project.

5. Conclusions

This paper has outlined key approaches the IACCIUS project has used to inform integrated assessment of climate change impacts on urban settlements in Australia. While still in a developmental stage it is expected that these approaches and the conceptual framework will provide the background needed to undertake IA using holistic, systems thinking rather than conventional thinking and traditional assessment approaches. While the methodology and framework are still in their infancy, they provide a promising approach that can allow for the uptake of innovative methods not normally used together in one project. The power of this approach, including any practical findings and lessons learned, are to be reported in a subsequent paper.

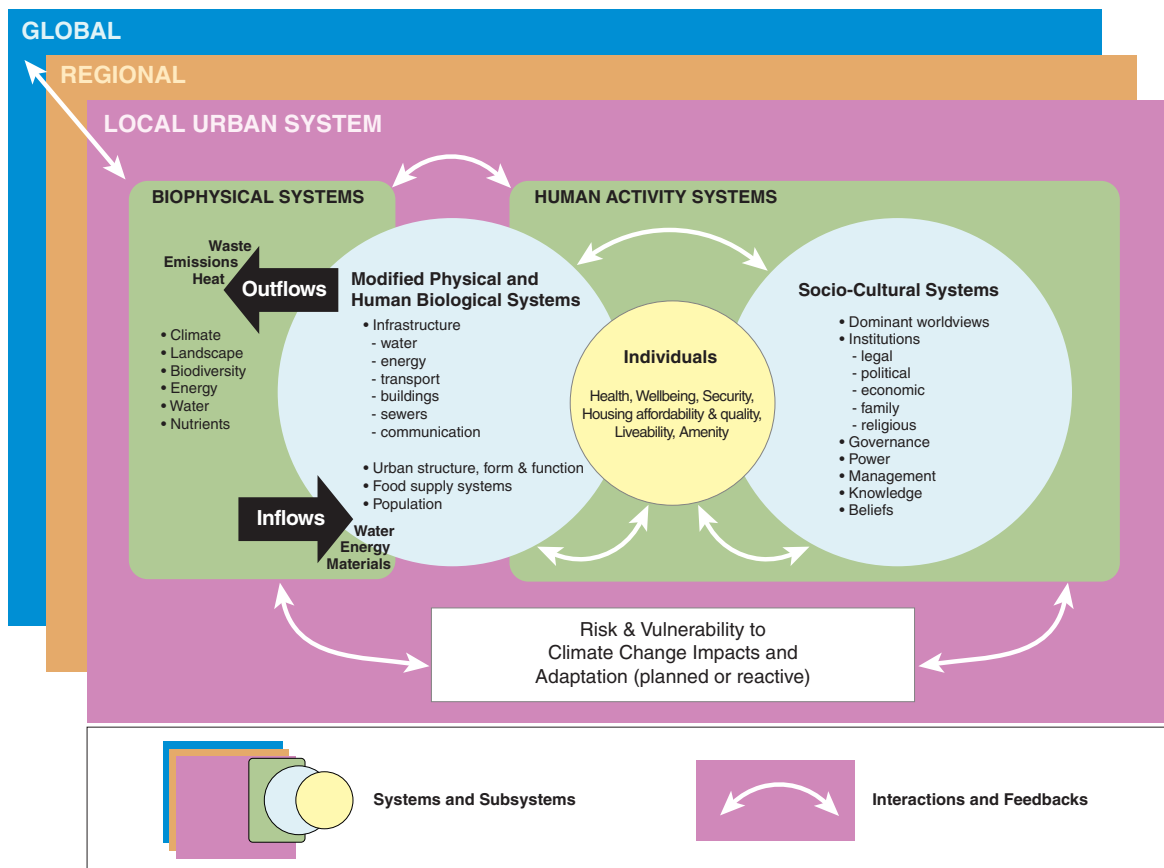


Figure 3. IACCIUS Conceptual Framework

6. Acknowledgements

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