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Methodological and Practical Insights from Australian Research on Urban Climate Change Impacts and Adaptation

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ABSTRACT

Cities and towns will house the majority of the world's population in future, and these human habitats will be impacted upon by predicted climate change. In the last two years, attention has shifted from (i) whether climate change will happen and to what extent, toward what societies' responses should be, and (ii) from a largely natural science-led debate to one where social science and professional and community knowledge are called upon. As coarser scale scenarios generated from climate models have become more accepted, there is now increasing focus on understanding climate change at finer scales to inform responses at the local and municipal level which is where many policy and management decisions are made. This paper presents insights for climate change impact assessment methodologies and practical adaptive responses for small-medium scale urban settlements, drawing on an integrated assessment (IA) of five Australian settlements. The paper outlines the IA methodology developed – Integrated Systems Risk and Vulnerability Assessment – how selected climate impacts were investigated, and summarises insights into the practice of local scale assessment and adaptation.

ABSTRAK

Majoriti penduduk dunia pada masa depan akan terdapat di bandaraya dan bandar, dan habitat manusia tersebut akan menerima impak perubahan iklim yang diramalkan. Dalam dua tahun yang lalu, perhatian telah beralih daripada (i) sama ada perubahan iklim akan berlaku dan setakat mana, kepada apakah bentuk respon masyarakat, dan (ii) daripada perbahasan yang diterajui oleh sains tulen kepada penglibatan pengetahuan sains sosial, para profesional dan masyarakat. Apabila senario skala lebih besar yang dihasilkan oleh model iklim telah lebih diterima, kini terdapat tumpuan yang bertambah dalam memahami perubahan iklim pada skala lebih kecil untuk diterapkan respon pada aras tempatan dan perbandaran di mana banyak dasar dan penetapan pengurusan dilakukan. Artikel ini memaparkan metodologi penilaian impak perubahan iklim dan respon penyesuaian praktikal untuk petempatan bandar skala sederhana-

kecil berdasarkan penilaian bersepadu (IA) lima petempatan Australia. Makalah ini melakarkan metodologi IA yang dibangunkan – Sistem Risiko Bersepadu dan Penilaian Kebolehterancaman – bagaimana impak iklim terpilih disiasat, dan meringkaskan pandangan terhadap pelaksanaan penilaian dan penyesuaian skala tempatan.

INTRODUCTION

Cities and towns will house the majority of the human population in future, and these habitats will be impacted upon by current and predicted climate change. There have been two recent and highly significant shifts in research and policy discussion around climate change. The first is that, following two decades where attention has centred on the natural science investigations of whether and to what extent human-induced climate change was occurring, there is now, especially since the IPCC (2007) 4th Assessment Report, majority acceptance in scientific and policy circles that it is and will happen. Consequently, attention has shifted to the nature of required policy and management responses. Second, with this shift in attention to responses to the accepted prospect of climate change, spatial and political scales of concern have changed. As well as the previous scale of the global and regional (sub-national) scales of climate modelling and impact assessment, much more attention is being paid to the national and local scales where policy and management responses will be constructed.

This paper deals with the local settlement scale where highly relevant decisions concerning such matters as urban planning, water management, emergency management, maintenance of open spaces and service provision are made. Although informed or regulated by national and international policy and policy processes, such decisions are made by state/provincial government agencies, local municipal councils, local businesses and communities. As these organisations and individuals seek to understand and respond to climate change, there is an emerging need for making sense of climate change locally, for fine scale data, and for ways of assessing the implications of climate impacts for local economies, societies and environments.

This paper focuses on small-medium urban settlements, and on how climate impacts and adaptation options can be assessed in an integrated manner. It draws on a multi-case study assessment of five Australian settlements, in an applied research project underpinned by (i) a

commitment to participatory research, (ii) the aim to develop operational assessment processes, and (iii) am integrated, systems-oriented methodology. It explored the proposition that the challenge posed by climate change can be rendered more tractable by connection to local scale knowledge and management agendas, and is not always too dissimilar to those confronted by communities and governments in managing existing climate and other variability (Dovers 2008). That proposition invites a 'normalization' of climate adaptation, connected to existing agendas, empowering local agencies and communities, and drawing on local knowledge and skills, as opposed to a purely novel, externally-imposed threat.

THE IMPACT ASSESSMENT PROJECT

The research reported in this paper was one of several projects initiated under the Australian Government Department of Climate Change's Integrated Assessment of Settlements Sub-programme, which aimed to develop approaches and explore responses to climate impacts on urban areas. The Integrated Assessment of Climate Impacts on Urban Systems (IACCIUS) project reported here, via five case study settlements, had two aims (i) to develop and test a methodology for integrated assessment, and (ii) to investigate selected priority issues in each jurisdiction. (A cognate project, Systems Approaches to Regional Climate Change Adaptation Strategies in Metropolises, is detailed via www.sydnercoastal councils.com.au.)

In each settlement, the project undertook an overview risk and vulnerability assessment in partnership with local and state/territory government stakeholders, It used the participatory, systems-based ISRaVA process (see below). This involved workshops that developed complex influence diagrams and associated information to identify relevant factors, interactions, actors and information, followed by a detailed investigation of priority issues nominated by the research partners. Fine scale local climate histories were developed and used alongside coarser scale scenarios, to make climate change more meaningful at local scale and to reflect local differences (Hutchinson et al. 2008). Scenarios from standard climate models and local climate histories were supplemented by summary descriptions of predicted changes to extreme events (eg. an increase from two to seven heatwave days per summer, increased storminess and intense rainfall events). The settlements and specific issues investigated were:

- Bendigo in Victoria, population 90,000, an inland rural centre built on a gold-mining past, now servicing a rich agricultural district, with farming, educational, tourism and regional service industries. Issue: water supply and demand, and management of open space and recreation facilities in the face of worsening drought.
- Cooma, New South Wales, a rural town of 8000 people, the service town for the Snow Mountains Hydro-electric Scheme and surrounding pastoral districts, and the main access town to Australia's alpine tourism areas. Issue: economic impact on the town of decreasing tourism visitation caused by predicted decreased snow cover and increased wild fire occurrence in the alpine national parks.
- Queanbeyan, New South Wales, a rural city of 35,000 adjacent to but separately governed from the national capital of Canberra. Traditionally a rural service centre, but since the establishment of Canberra increasingly a dormitory suburb with diverse urban form. Issue: changes to urban land surface cover (increasing impervious surfaces) and possible stormwater runoff behaviour in the context of current and likely future increasing occurrence of drought and more frequent storm events.
- Canberra (330,000) the young, purpose-built and highly planned national capital of Australia. Issue: residential water consumption and effectiveness of demand management measures following prolonged drought and predicted future water shortages.
- Darwin (110,000), capital of the Northern Territory, with a high Indigenous and unusually mobile population, situated closer to Asia than to other Australian cities, in the cyclone-prone tropics. Issue: differential vulnerability to climate extremes, and water and energy consumption issues.

These settlements were selected to provide the research with a variety of urban character, socio-economic attributes and climatic zones and impacts. IACCIUS did not comprehensively analyse one place, but used the five different settlements as testing grounds in which to develop rigorous and practical approaches to assessing climate impacts, while investigating priority issues in each. IACCIUS organised two cross-project meetings with four other cognate projects being run elsewhere in

Australia, to allow comparison and learning between them. Most of the lessons reported here were evident in these other projects.

Both research and policy in the sustainability domain require integrated approaches to address the close interdependence of human and natural systems (Dovers 2005a). Integration in research incorporates knowledge across disciplines, whereas integration in policy connects agencies and sectors, and thus can either *inform* policy and/or more directly *formulate* policy. The IACCIUS project sought to inform policy through: (i) providing information to local agencies for their use; (ii) directing assessments into decision making via agency officials who participated in the project; and (iii) developing a methodology for IA elsewhere. However, the formulation of policy responses is the role of responsible authorities, not of an external assessment team.

Integrated assessment seeks to incorporate multiple drivers and impacts of climate change, using some form of systems-oriented framework and a diversity of specific methods. Most attention has been on regional scale, non-urban systems and sectors (eg. Fischer et al. 2005; Holman et al. 2005; Krol & Bronstert 2007; Letcher et al. 2007; Lange 2008), and on use of computer-generated or quantitative models (Risbey et al. 1996; Garg et al. 2007). While some work has included urban settlements (eg. Mediavilla-Sahagun & ApSimon 2006) the majority have not applied a participatory, integrative systems methodology focussed on local urban impacts and implications.

The IACCIUS project addresses that gap by developing an initial approach (see Li 2008) and testing and further developing this through case studies. Most work to date has focussed on the northern hemisphere (eg. Edmonds & Rosenberg 2005; Holman et al. 2005; Kirshen et al. 2008; Lange 2008). IACCIUS developed its methodology in the context of smaller towns and cities, within the Australian context, treating these settlements as complex adaptive human-environment systems, and emphasising local realities, information need and decision making. Settlements are not static, independent entities, but parts of the world influenced by interactions of humans and their environments, and are complex and constantly adapting to internal and external pressures. Such settings require approaches that are integrative, suited to the urban context, flexible, critical and adaptive.

To address these requirements, the IACCIUS methodology draws on a range of theoretical and methodological fields, including the following (for detail, see Li 2008; Li et al. 2008):

- Climate science, being consistent with global climate models and scenarios, but translated into a manner relevant to local decision making.
- Critical realism and adaptive theory, being cognisant of multiple claims to knowledge and to the need to iterate between theory and empirical observation.
- Participatory research methods, allowing the engagement of local knowledge and agencies from the start of the research process.
- Systems thinking and tools, to ensure capture of multiple factors and interactions.
- Urban studies, to draw on the accrued understanding of human settlements, their form, structure and function.
- Public policy, public administration and institutional design, to allow better connection with considerations of policy and decision making.
- Risk management, and analysis of uncertainty, being central to consideration of climate impact, and providing widely used, relevant tools.
- Vulnerability analysis, and emerging area of particular relevance to socio-economic assessment of climate impacts at local scale.

Informed by these theoretical and methodological fields, and tested through application across five settlements, a methodological framework termed Integrative Systems Risk and Vulnerability Assessment (ISRaVA) was developed, and is summarised in Box 1 (for detail see Li et al. 2008). Integrated assessment is a process and intent described by a methodological framework and will utilise diverse methods and tools in different contexts. Box 2 provides a sample of the diversity of methods that may be applied to assessing climate impacts and response options, depending on local context and issues. The ISRaVA methodology (i) is based on appropriate roots in relevant disciplines, (ii) balances rigour with flexibility in varying practical contexts, (iii) allows capture of multiple, interacting factors, and (iv) was proven to be accessible and operational in a local decision making context.

The IACCIUS approach, and the ISRaVA process, adhere to commonly used terms and concepts in climate adaptation literature and policy (eg. risk, vulnerability, adaptive capacity, etc), and in particular has maintained a consistency with existing risk management processes (eg. Standards Australia 2004). However, it extends these through

explicit use of participatory, systems approaches, treatment of residual uncertainty, and suitability to local scale climate impacts assessment.

The following two sections summarise some of the main practical insights derived from the development and application of the ISRaVA methodology, to inform applications elsewhere, whether following the same or a similar approach. These insights portray the promise and the challenges of local scale climate impact and adaptation assessment.

Box 1. The Integrative Systems Risk and Vulnerability Assessment (ISRaVA) process

Establishing the Context

1. Accept the problem of local urban scale climate change impacts as a complex adaptive human-environment system problem, requiring whole-of-system and whole-of-government engagement and response
2. Study, to understand within uncertainty limits, past present and future local climate change and variability

Identifying and analyzing what's at risk/vulnerabilities

3. Conduct a participatory urban system risk analysis process that:
   - 'teaches' participants basic systems concepts and associated tools
   - enables the agreement of where to place system boundaries
   - identifies urban system parts at risk of climate change impacts
   - identifies key constraining relationships between system parts
   - collectively constructs influence diagrams of the urban system
   - identifies systems and subsystems of interest
   - identifies priority subsystems for further in-depth investigation
4. Develop a communication and feedback system between researcher and stakeholder as the research proceeds, especially as may be related to concurrent policy processes
5. Identify relevant policy history and ongoing policy processes that may be relevant to the research process
6. Assess vulnerability for the priority subsystems of interest by using appropriate methods to collect and analyse primary or secondary data that:
   - enables a better understanding of the parts of the system at risk (exposure units)
   - enables a qualitative or quantitative description of system sensitivities
   - enables an exploration of past and present adaptation actions taken,

future possible strategies, and, where possible, adaptive capacities
- enables a more in-depth systems analysis taking into account vulnerability findings (this may appear as reworked influence diagrams, or a more detailed systems model)

7. In the assessment of vulnerability use participatory processes with stakeholders to further identify future possible adaptation strategies, and current and future capacities to adapt, including possible policy recommendations

Evaluating and reviewing the process

8. Identify gaps in the analysis that may require:
   - further research or investigation
   - the collection of further primary or secondary data to fill data gaps
9. Finalise and write up analyses, disseminate and communicate findings to all stakeholders

Treating the risks/vulnerabilities

10. Stakeholders responsible for urban adaptation strategies and policy-making to:
    - take into account findings of the integrated assessment and commence or continue management and the policy-making and implementation process
    - iterate through any of the above steps as required

Source: Li 2008; Li et al. 2008

Box 2. Methods to support integrated assessment

Goal	Method
Social and environmental assessment	Risk and vulnerability assessment; social and environmental impact assessment; strategic environmental assessment; sustainability assessment; ecological footprint analysis; material flows analysis; life cycle analysis; state of environment reporting
Systems analysis	Systems tools; influence/causal loop diagrams; time series analysis; stock and flow modeling; group model building
Decision analysis	Game theory, Bayesian decision networks; meta-models, agent-based modelling, expert systems; coupled-component; multi-criteria analysis

Spatial analysis	Demographic mapping; hazard mapping; remote sensing; geostatistics
Policy analysis	Policy monitoring and evaluation; historical policy analysis; scenario planning; comparative policy analysis; policy instrument choice analysis
Economic analysis	Triple-bottom-line, cost-benefit analysis; non-market valuation; natural resource accounting
Historical analysis	Historical policy analysis; oral/environmental history; ethnographies
Discourse and document analysis	Government, private, archived, internet, newspaper, academic literature, local knowledge.
Participatory and deliberative methods	Workshops; surveys; interviews; participatory modelling; scenario building; local information gathering; focus groups, joint problem-framing; citizens juries; consensus conferences; team-work approaches.

Source: Li 2008; Li et al. 2008

METHODOLOGICAL LESSONS

The case settlement applications of the IACCIUS/ISRaVA methodology showed that there is strong potential of a systems-oriented, participatory approach to identifying climate risks and vulnerabilities at a local scale. The benefits accrued through the generation of locally relevant climate information, the overview risk and vulnerability assessments, and through more detailed assessment of specific issues. The participatory approach produced joint learning, increased agency awareness of climate change impacts, and allowed local imperatives to be identified and pursued. It was apparent that the potential magnitude of a comprehensive IA exercise is significant – the combined range of climate impacts and potentially affected people and assets create a problem set too large for a single or swift assessment to deal with. Prioritisation is required, and the following methodological lessons suggest ways to render IA more practical through design and scoping of assessments.

There emerged a need to consolidate and communicate available methodologies and tools for integrated assessment (whether an approach is termed such or not). Climate change is a relatively new issue for many

local agencies and communities, and one yet to be fitted into existing decision-making, human resource and informational capacities. More local agencies are investigating the implications of climate change, and wide communication of methods and applications would assist in driving a more rapid, rigorous and efficient assessment of risks and vulnerabilities and development of response options. It would also allow testing and improving approaches through further testing and evaluation.

Local agencies require understanding not only of ways in which to investigate climate change implications, but the time and resources needed to do so. IA is demanding of skills, and the precise needs are difficult to predict until overview assessments have identified priority issues. Then it may be clearer whether demographic, climate science, economic, hydrological, engineering, GIS, etc skills are needed. IACCIUS recorded the work days required for some tasks, to indicate the level of commitment (the cost will vary with whether the work is undertaken by an agency or by external, commissioned teams):

- An overview ISRaVA workshop process, including necessary background research, running the process, synthesising outcomes, and communication: 15-30 work days by the assessment team, and ~10 by stakeholders, totalling 25-40 days.
- Investigation of a specific priority issue will vary. In Darwin, the differential vulnerability assessment was estimated at 55 workdays by assessors and 15 by stakeholders, totalling 70 days. In Queanbeyan, 35 assessor work days and 5 stakeholder days were needed, totalling 40.
- Preparation of local climate histories to supplement the coarser scale climate scenarios, approximately 20-30 work days, and demanding advanced meteorological and mathematical skills.
- In total, an overview assessment, localising of climate science and investigation of around 4-5 priority issues – possible the desired scope and detail required by a municipal council or similar body – would require in the order of 200-250 work days.

These are not insignificant commitments for a local agency, especially a small one, and most local agencies are resource poor. Behind the time commitment lie issues of data and skills. Consistent with the range of methods that might be applied in an IA (Box 2), there is a demand for acquisition, management and analysis of diverse complex data sets, such as energy and water consumption, local climate records, demographic data, remotely sensed topographic and other land surface data, economic data, etc, usually needing spatial representation and

manipulation. Three practical issues arise. First, many existing data sets will not be suited for the required use because of coarse spatial resolution, limited length of time series, patchy coverage or less than desirable quality. Second, large and diverse data sets will require a sophisticated data management system, the provision and servicing of which need to be included in project design and funding, and will likely require ongoing maintenance and updating if managing climate variability is to be incorporated into decision making procedures. Third, difficulties may arise in accessing data, through cost of purchase from external providers, time constraints or lack of interest on the part of data custodians, or commercial-in-confidence or privacy provisions. Often, key data custodians will not be included in original project design but be identified later, and custodians may not be committed to or accept the importance of the assessment.

It is not surprising that existing data will be unsuitable, as an integrated assessment of climate impacts and response options will ask different questions, at different scales, and existing data systems will not have been set up to answer these. A benefit of an IA exercise is often to identify data shortages that, if filled, may be useful for other planning and policy needs.

The range of data and analytical demands invites an often demanding array of skills. Investigation of specific issues may require skills in statistics, demography, local economic profiling, policy analysis, climate science, hydrology, engineering and asset appraisal or risk assessment, as well as generic skills in workshop facilitation, communication, and project management. Assessment teams and local agencies will be pressed to provide all these, or to easily or affordably access them.

Critical to local scale assessment of the implications of climate change is an established connection to local decision making and cycles of planning and policy in relevant agencies. Participatory IA exercises such as IACCIUS will ensure some connection by including local decision makers such as municipal planners or engineers. However, it is important for external assessment teams to identify and understand local policy processes and to match the assessment process and outputs to these. A municipal council, for example, may undertake strategic planning once every three or five years, and an IA reporting at the right time in this cycle may be very timely, whereas one reporting too late in the cycle or just after completion of a plan may not be incorporated another few years, and likely be out of date.

To establish such connection, and to undertake a participatory assessment exercise by external contracted research or consultant teams, the development of trust and positive relationships, and understanding of local imperatives, may take considerable time and effort.

Wide representation from local agencies is an essential element, especially in the overview assessment phase, to ensure that all impacts, risks, vulnerabilities and interests are identified, and so that interactions between these are mapped. A systems mapping exercise can only reflect the input to it, and in an integrated assessment of a cross-sectoral issues like climate change this invites a wide array of professional and community input – health, environmental protection, infrastructure, open space and reserve management, transport, emergency management, etc. Wide participation in the initial stages will serve to ensure the likelihood of collaboration in subsequent investigation of specific issues. Agency-wide participation generally will require support by senior or central people in an agency (eg. general manager or mayor of a local council, or the central planning or similar agency at state/territory level).

Considering the above lessons, and the potential demands on limited local resources, the IACCIUS project has recommended that IA and similar approaches are best undertaken, in the interests of effectiveness and efficiency, in three stages, reflecting the ISRaVA process (Box 1) and in the following sequence:

1. A systems-oriented overview assessment of climate impacts, risks and vulnerabilities. This would lead to a stakeholder-led prioritisation of key issues requiring more detailed, time- and data-intensive investigation, allowing definition of the required methods, resources, data and skills.
2. Project refined to mount detailed analyses of selected priority issues identified in stage 1, deploying identified skills and methods.
3. Re-integration of findings of detailed investigations against the overview assessment to capture cross-sectoral interactions (eg. impact of water demand management on public health, or emergency management evacuation plans on public transport).

A final issue is the fate of knowledge and options developed during what will often be an externally-delivered, ‘one-off’ assessment process. Even with good connection to local policy processes, there is the need to integrate climate change considerations into ongoing information and decision making processes. The legacy of heightened awareness and

information capacities produced have some impact, however measures to ensure ongoing maintenance of information on climate impacts, vulnerabilities and the success of any implemented adaptation measures will be required. This will demand coordination between parts of local agencies such as planning, engineering and open space, water and energy management, etc. This issue of climate policy integration across portfolios, departments and policy sectors at all levels of government deserves further attention.

PRACTICAL APPLICATIONS

The methodological issues above are generic to any local integrated assessment (IA). This section illustrates the kind of practical adaptation options that can emerge, using examples from the five IACCIUS case settlements. (The following identifies options, whereas implementation of these is a matter for local and other organisations beyond the life of the IACCIUS project which was completed September 2008).

In the rural Victorian city of Bendigo, IACCIUS investigated the impacts of current and likely drought and water shortages under changed climatic conditions, in the context of recent, severe drought This priority emerged from the local council and stakeholders, with outdoor sport and recreation and the visual character associated with these facilities being important for local lifestyles, public health and cultural identity, and to the economy through hosting major sporting events. While on a wider scale the survival of sporting activities may not feature in climate debates, at a local scale such priorities are central to regional settlements and the responsibilities of local governments. Although already familiar with drought and actively managing water shortages, new insights emerged from the analysis. One was equity issues identified from socio-economic and spatial analysis of access to remaining facilities across the community, which varied according to location, socio-economic status and mobility, and the need to factor this into facility planning. Another equity issue was the possible under-resourcing of non-water dependent activities (eg. indoor sports) at a time when investments may be skewed toward maintenance of water-dependent activities. Also identified were differential impacts on sports and recreational activities tied to their relative water (or grass cover) dependence, and thus a better understanding of varied opportunities to decouple use from water availability.

In Canberra, the intent was to investigate fine scale water and energy consumption of households, to explore the impact and potential of

appliance rebate and other demand management interventions as strategies for ongoing adaptation to predicted increased climate variability. Existing data sets for water and energy consumption are generally not organised in a manner suitable for such investigations, being averaged over settlement and suburb level and historically organised for billing rather than consumption analysis. Property scale data is required, that can be then manipulated according to housing form and socio-economic and demographic variables, and the uptake of rebates and other demand management mechanisms (Troy et al. 2005). Although previously made available in Canberra and other cities, these data were not made available to the project on privacy grounds, and the analysis could not proceed. This emphasises the importance of data suitability and availability issues noted above, and of gaining collaboration of data custodians in a timely fashion.

In Cooma, local stakeholders identified climate change-driven threats to the tourism income of the area as a priority, with specific reference to declining snow cover and impact of wild fires on the nearby tourist destinations within the alpine national parks. This required confirmation of past and likely future event scenarios using climate projections and local climate history along with forecast impacts on visitation rates. It was not considered useful to attempt to project future visitation numbers and thus economic impact in the face of uncertain climate projections. Instead, IACCIUS examined the impact of past poor snow and major fire seasons, which revealed (i) some inadequacies in past visitation data, and (ii) somewhat less and highly differentiated impacts of poor seasons than expected. Visitation in the core tourist season was less affected by poor snow cover than expected, although the more accomplished skiers and the marginal periods early and late in the season were more vulnerable. Wild fires emerged as a major impact on summer visitation. Through interviews with local tourist-dependent businesses, it was revealed that some had already adapted to existing climate variability in ways that prepared them for future increased variability.

A major qualification was that, while previous adaptations to variability were evident, the local economy had yet to experience a sequence of poor seasons, and if this occurred in future the impact may be far more severe. It was concluded that many options for ensuring resilience in the local economy to climate change and variability were similar to familiar strategies recommended for local economic development, These strategies include better knowledge of local economic trends, better visitation data and understanding of the visitor

market, coordinated land use planning, economic diversification, development of local skills, and improved marketing and communication efforts. Also revealed was a finer scale understanding of roles and responsibilities for local climate assessment and adaptation, across local businesses and communities, local government, wider industry associations, and state and national levels of government. This may inform coordination and efficiencies in data provision and adaptive strategies.

In tropical Darwin, the threat of heat stress and particularly increased cyclone intensity dominated, and from this emerged the need to better understand differential vulnerability across the city using fine scale spatial, biophysical and socio-economic and population data. This approach allowed identification of areas within the city where a combination of these factors indicated varying levels of vulnerability and adaptive capacity to different climate impacts. It also allowed initial analysis of the adequacy of some adaptation measures, such as the distribution of cyclone shelters when analysed against population distribution and mobility. Areas of potential improvement were identified in data availability to describe important variables such as fine scale water and energy demand, population turnover and socio-economic status, threats such as storm surge, and building stock characteristics. Again, existing data and information pathways will be tested by the new questions posed by local climate impact assessments, and an IA process may identify improvements in data gathering and distribution useful for other, existing needs such as public health, emergency management or building stock assessment and improvement.

In Queanbeyan, drought and rapid urban development had produced changed characteristics in urban land surface cover, intensified by shifts in household landscape preferences and loss of grass cover and replacement of this with landscaping products in the face of drought and water restrictions. More frequent dry periods and increase in intense rainfall events are predicted with climate change. Urban water runoff is accelerated and stormwater management may be complicated by the combination of changed landscape surface and these climate impacts. Beneath an assumed impervious surface proportion of ~40% for suburban landscapes, innovative fine scale analysis of remotely-sensed data revealed a range between 17 and over 80% across the settlement, depending on urban form and housing stock age. High imperviousness in newer, low density developments was an unexpected finding, while in older medium density areas this was expected. Such insights may inform future subdivision layout, landscaping requirements and stormwater

provision. Opportunities emerged for improvement of remotely-sensed data and management of urban surfaces (eg. pervious artificial materials, drought-tolerant grass species, etc). As in Bendigo, this case evidences the sometimes unexpected priorities arising from engagement with local agencies, and the difficulties of developing climate adaptation responses when the cause of a potential problem is the cumulative result of sum of many, seemingly insignificant property scale decisions and actions.

Across the case studies, and from other local scale assessments, issues of political and other sensitivities arose. Broader scale climate policy debates identify more sensitive regions, sectors and sub-sets of populations affected by direct climate impacts, indirect physical or economic impacts, and implications of policy responses. Locally, though, impacts and implications are likely to be identified at individual property or firm scale. This personalises the issue of climate change in what may be a highly politically sensitive manner, raising issues of business viability, individual household vulnerability, property prices, and liability. This cannot be avoided if we are to assess and respond to climate change at the local scale where many planning and other decisions are made. Assessment processes, and any adaptation responses that may arise, must at least recognise this sensitivity and plan the participatory assessment process and communication strategy accordingly.

Such sensitivities, and practical issues of decision making, are confounded by the uncertainties associated with predicted climate changes and impacts, uncertainties that are further compounded by the current state of fine scale data and understanding of assets and services that may be impacted on. Decision making in the face of uncertainty is central to climate change policy, and is more broadly an area that requires significant attention (Dovers 2006; Bammer & Smithson 2008). In local applications of climate impact assessment, there are evident disparities in how uncertainty is understood, and in the standards of proof and expectations of accuracy in prediction of future impacts. That is a specific challenge for informing decision making at local scales. IA or any other approach will not produce definitive predictions or clear management instructions, but will rather produce new, useful insights into possible impacts and responses, to be considered alongside other imperatives facing local agencies and communities.

CONCLUSION

This paper has summarised a methodology developed and tested in five diverse, small-medium Australian settlements, and indicated some of the fine scale practical impacts and response options identified. The ISRaVA process – or some similar integrated assessment approach using multiple methods – was found to offer significant potential to inform local discussions and decision around climate change adaptation. As with other applications of IA, there is more methodological development and testing required, and a need to synthesise and communicate methods, but there is a sufficient basis to progress with further practical applications.

A significant benefit in utilising participatory, systems-based methods lies in the closer connection to local knowledge and management agendas, and to the decision making cycles of local agencies. The down-scaling of climate science and connection of broader climate scenarios to local extreme event possibilities and past and current climate variability provides a connection to local experience that serves to 'normalise' climate change rather than present it as a completely new, externally derived threat. In this way, IA can empower local agencies and communities in dealing with climate change.

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