Presenter: **Rule, Bridget**
Other authors: **Boyle, Dr. Carol**
Institution: University of Auckland
Postal address: Department of Civil and Environmental Engineering, Faculty of Engineering, The University of Auckland, Private Bag 92019, Auckland Mail Centre, Auckland 1142
Telephone: 027 327 3327; fax: 09 373 7462; email: brul001@aucklanduni.ac.nz
Title: **Challenges for sustainable infrastructure development in small island developing states**
Stream: Resilient Societies

Abstract

The ongoing viability of many small island developing states (SIDS) is under pressure from factors including climate change, sea level rise, and their usually high dependence on imported food, energy, and manufactured goods. Sustainable, resilient development is a necessity for SIDS if they are to ensure their ability to maintain and improve their populations' quality of life in the face of these challenges. Infrastructure that supports sustainability is therefore a key element to SIDS development, but SIDS have historically had major issues with infrastructure development, centring on economies of scale as they tend to have small, dispersed populations, combined with few natural resources and limited funds. Pinpointing exactly what can be done to improve SIDS' resilience through sustainable development requires first pinpointing their main sustainability and development issues in greater detail, and looking at salient characteristics country by country. Examining SIDS in this manner reveals that they have as many characteristics setting them apart from one another as they have in common. As such, while SIDS' present and historical development issues have common threads, their future opportunities and pathways to resilient, sustainable societies may be very different. In determining whether and how individual SIDS could become sustainable, the concept of urban metabolism may be useful through measuring SIDS' endemic ability to support their populations.

Introduction

Small island developing states (SIDS) have a unique set of development issues, most of which relate to issues of scale and isolation (Kerr, 2005). The United Nations Department of Economic and Social Affairs in particular describes SIDS as low-lying coastal countries characterised by small population, a lack of resources, remoteness, susceptibility to natural disasters, excessive dependence on international trade, and costly public administration and infrastructure (UNDESA, 2003); this essentially reflects their high vulnerability, a sentiment echoed by the IPCC in its Fourth Assessment (Mimura et al., 2007). The excessive dependence on international trade referred to by the UNDESA is a major concern for SIDS, because much of this trade simply fulfils basic human needs, such as food – for example, Cape Verde imports over 80% of its food, mostly rice (CIA World Factbook, 2010a)–, manufactured goods, and energy, with an almost total dependence on imported fossil fuels for all energy needs, including electricity (through diesel generators) and transport (Krumdieck and Hamm, 2009). At present, due to the availability of foreign goods and pursuit of a Western lifestyle, SIDS tend to maintain a large imbalance between imports and exports. For example, the Tongan balance of trade (exports and re-exports less imports) has steadily worsened year on year since 1987, leaving a $264 million Palaga (approximately US$130 million) deficit in 2007 (Tongan Ministry of Finance and National Planning, 2008). As oil prices have generally been rising in recent years, shipping is only growing more expensive, yet as shown by Tonga, there is no decline in the demand for imported food and other goods. Adding to this lack of resources, SIDS often rely on limited groundwater for their water supply (Liu, Lin et al., 2006; Diamantopoulou and Voudouris, 2008). Saltwater intrusion is becoming a major problem for islands as extraction from freshwater lenses exceeds regeneration, and there are indications that sea level rise may accelerate salt intrusion (Mimura et al., 2007).

To this end, sustainable infrastructure issues remain a core focus for the UN-OHRLLS (the UN's SIDS special interest group), with climate change, freshwater resources, land resources, energy resources, transport, sustainable capacity development, and sustainable production and consumption featuring among 19 'priority areas' identified in 1992 (UN-OHRLLS, 2005). Since then, the Barbados Programme of Action (developed and adopted in 1999) narrowed the focus of SIDS development further down to six areas needing urgent attention: these include climate change (adaptation to climate change and rising sea levels); freshwater resources (preventing freshwater deficits as demand grows); energy (developing renewable energy, particularly solar, to lessen dependence on imported oil); and tourism (managing the growth of this sector to protect environmental and cultural integrity) (UN-OHRLLS, 2005).

In addition, island economies often lack diversity as they are based on very few resources, making them very sensitive to any changes in those industries. As SIDS often have distinctively large Exclusive Economic Zones (EEZ) relative to their landmasses, fishing and fishery licensing are vital to the economies of many SIDS (Kerr, 2005). Tourism often accounts for a large part of GDP, as island states make up 27 of the 31 countries of the world who generate more than 20% of their GDP through travel and tourism (Kerr, 2005). Aside from this, foreign aid and remittances feature heavily in contributors to SIDS' GDP. For example, 20% of Cape Verde's GDP comes from remittances sent by Cape Verdeans living overseas (CIA World Factbook, 2010a), and this level of support is not uncommon. External subsidies and preferential trade agreements are also widespread in island economies, especially among overseas territories and former colonies (Kerr, 2005).

Describing SIDS

At this point it may be helpful to consider the individual countries labelled SIDS, rather than the group as a whole, to understand why SIDS have been grouped as such. The UN-OHRLLS lists 52 SIDS, of which 38 are UN members and 14 are non-members, or are associate members of the regional commissions. However, the definition 'small island developing state' appears to be a loose one; many of the SIDS listed by the UN-OHRLLS lack one or more of the descriptions implied by the title 'SIDS'. Table 1 sets out the SIDS (as listed by the UN-OHRLLS) and their characteristics (i.e., how well they fit the grouping 'small island developing state'), in the context of determining their vulnerability, as per the UNDESA description (UNDESA, 2003). For this purpose, 'small' has been somewhat arbitrarily defined as being less than 20,000 square kilometres in continuous landmass (0.01% or less of the total land area of the world), and having a population of less than 1 million (0.015% or less of the total population of the world) (CIA World Factbook, 2010b). 'Island' has been defined both literally (whether unconnected to a continental landmass) and in terms of remoteness (the distance to the nearest continental landmass). The concept of 'developing' lies on a spectrum and as such is difficult to accurately define, so human development index (HDI) (UNDP, 2010) and net official foreign development aid per capita

Table 1: Classification of SIDS. Data sources: UN-OHRLLS (2010), CIA World Factbook (2010b), the World Bank (2010), and UNDP (2010).

SIDS (as listed by UN-OHRLLS)	Small		Island		Developing		State
	Less than 20,000 km^2 continuous landmass	Population of less than 1 million	Not connected by land to a continent	Distance from main port to nearest major landmass (km)[(a)]	Foreign aid received per capita (US dollars)[(b)]	HDI 2007[(c)]	Level of autonomy
American Samoa	√	√	√	2711	N/A[(d)]	N/A	Overseas territory (US); non-UN[(e)]
Anguilla	√	√	√	823	N/A	N/A	Overseas territory (UK); non-UN
Antigua and Barbuda	√	√	√	709	$66.57	0.868	√
Aruba	√	√	√	33	-$114.15[+]	N/A	Domestic autonomy (under Netherlands)
Bahamas (The)	√	√	√	132	$14.78[+]	0.856	√
Bahrain	√	√	√	44	$80.69[+]	0.895	√
Barbados	√	√	√	388	$37.29	0.903	√
Belize	X	√	X	0	$54.75	0.772	√
British Virgin Islands	√	√	√	867	N/A	N/A	Overseas territory (UK); non-UN
Cape Verde	√	√	√	646	$340.77	0.708*	√
Comoros	√	√	√	315	$52.22	0.576*	√
Cook Islands	√	√	√	2777	N/A	N/A	Domestic autonomy (free association: NZ)
Cuba	X	X	√	235	$9.04	0.863	√
Dominica	√	√	√	517	$308.04	0.814	√
Dominican Republic	X	X	land border	688	$10.18	0.777	√
Fiji	√	√	√	1887	$68.10	0.741	√
French Polynesia	√	√	√	3832	$2,304.12[+]	N/A	Overseas territory (France); non-UN
Grenada	√	√	√	157	$293.57	0.813	√
Guam	√	√	√	2399	N/A	N/A	Overseas territory (US); non-UN
Guinea-Bissau	X	√	X	0	$65.50	0.396*	√
Guyana	X	√	X	0	$201.50	0.729	√
Haiti	X	X	land border	814	$60.06	0.532*	√

	Small		Island		Developing		State
Jamaica	√	X	√	677	$20.05	0.766	√
Kiribati	√	√	√	3539	$267.67	N/A*	√
Maldives	√	√	√	611	$157.17	0.771*	√
Marshall Islands	√	√	√	3732	$940.77	N/A	Domestic autonomy (free association: US)
Mauritius	√	X	√	876	$42.14	0.804	√
Micronesia (Federated States of)	√	√	√	2131	$930.10	N/A	Domestic autonomy (free association: US)
Montserrat	√	√	√	660	N/A	N/A	Overseas territory (UK); non-UN
Nauru	√	√	√	2867	N/A	N/A	√
Netherlands Antilles	√	√	√	78	$115.75[+]	N/A	Domestic autonomy (under Netherlands)
New Caledonia	√	√	√	1416	$2,279.07[+]	N/A	Overseas territory (France); non-UN
Niue	√	√	√	2358	N/A	N/A	Domestic autonomy (free association: NZ)
Northern Marianas	√	√	√	2266	N/A	N/A	Domestic autonomy (political union: US)
Palau	√	√	√	1695	$1,452.45	N/A	Domestic autonomy (free association: US)
Papua New Guinea	X	X	land border	659	$45.97	0.541	√
Puerto Rico	√	X	√	735	N/A	N/A	Overseas territory (US); non-UN
Saint Kitts and Nevis	√	√	√	724	$234.19	0.838	√
Saint Lucia	√	√	√	362	$54.13	0.821	√
Saint Vincent and the Grenadines	√	√	√	292	$206.24	0.772	√
Samoa	√	√	√	2752	N/A	0.771*	√
São Tomé and Principe	√	√	√	268	$219.45	0.651*	√
Seychelles	√	√	√	1085	$141.22	0.845	√
Singapore	√	√	√	0.7	N/A	0.944	√
Solomon Islands	√	√	√	1479	$407.12	0.610*	√
Suriname	X	√	X	0	$177.00	0.769	√
Timor-Lesté (East Timor)	√	X	√	585	$214.66	0.489*	√
Tonga	√	√	√	1873	$252.49	0.768	√
Trinidad and Tobago	√	X	√	31	$6.47	0.837	√

	Small		Island		Developing		State
Tuvalu	√	√	√	2932	N/A	N/A *	√
US Virgin Islands	√	√	√	788	N/A	N/A	Overseas territory (US); non-UN
Vanuatu	√	√	√	1801	$245.30	0.693*	√

Notes:
(a.) Values shown are the shortest distance from any of the major ports (if more than one) to any point on a continent or other major landmass (including Borneo, Japan, Madagascar, and New Zealand). Dark pink: < 1 km; Light pink: 1 to 50 km; Light green: 50 to 500 km; Dark green: > 500 km.
(b.) 2004–2008 average based on available data (not all years are available for all countries), in current US dollars (2010). Dark pink: no aid received; Light green: $0 to $200 received; Dark green: > $200 received.
(c.) HDI categories: Dark pink: very high development; Light pink: high development; Light green: medium development; Dark green: low development.
(d.) N/A: Not available.
(e.) non-UN: is not a UN member but may be an associate member of the regional commission.
* Denotes also a UN-classified least developed country (LDC).
\+ Denotes only 2004 data available.

(World Bank, 2010) have been used, in keeping with the context of assessing vulnerability. ‘State’ is defined by level of autonomy, ranging from fully dependent territories to fully independent nations (CIA World Factbook, 2010b).

Table 1 reflects that depending on how each parameter is defined, many SIDS are lacking in one or more aspects of their definition. Yet, no matter their size, neighbours, socioeconomic success or degree of autonomy, one aspect shared by all the entities on the UN list is the risk posed by climate change, as revealed by their presence as a single group (‘small islands’) in the IPCC’s Fourth Assessment (Mimura et al., 2007).

Climate change

Climate change is a particularly insidious threat to SIDS, as they account for some of the most vulnerable areas in the world, especially if sea levels rise as the IPCC predicts: between 18 and 59 centimetres by 2100, excluding glacial melting (Mimura et al., 2007). Other estimates come up much higher: a team at NASA Goddard assume that feedback mechanisms will accelerate ice-melt in Antarctica and Greenland, resulting in a global sea-level rise of up to 25 metres by 2100; and even more conservative models that ignore feedback scenarios estimate the rise at 1.4 metres by 2100 (Vince, 2009). Other anticipated effects are increases in extreme weather frequency and intensity, meaning it is likely that there will be more cyclones (and they will tend to be stronger), longer intervals between rainfall causing droughts in the dry season, and heavier storms in the wet season leading to flooding; stronger and more frequent storm surges are expected, along with changes in temperature which may make it more difficult for indigenous species to compete with introduced species (Mimura et al., 2007). Worse still, higher sea temperatures combined with agricultural (nutrient) and industrial (chemical) pollution are causing coral bleaching and seagrass degradation, two habitats vital for fisheries and tourism as well as general ecosystem health (Mimura et al., 2007).

But there is reason to believe that SIDS have a reasonable chance of surviving climate change. A recent study showed that of 27 Pacific atolls, the most low-lying and therefore most vulnerable type of island, the rate of growth by natural build-up of dead corals of the islands studied outpaced the rate of sea level rise (two millimetres per year) over the 60-year study period (Webb and Kerch, 2010). Although the rate of sea level rise is believed to be accelerating (Zukerman, 2010) this study indicates that the geographical areas perceived as being the most vulnerable to climate change still have a fighting chance of maintaining their way of life. However, if sea levels rise this century as much as some models predict, islands whose highest point is less than 25 metres (or not much higher than that, depending on the terrain) have a lower chance of surviving sea level rise over the next 90 years. However, a rise of 25 metres is considered to be the worst case scenario with most models showing significantly less than that, and the vast majority of SIDS exceed 25 metres in height at their highest point (CIA World Factbook, 2010b), the exceptions being the Marshall Islands, the Maldives, and Tuvalu. The main issue with sea level rise, then, lies with the fact that the majority of SIDS infrastructure is very close to the coast, including roads, airports, and population centres (especially capital cities, which are often based around the main port). In the Caribbean and Pacific Islands, more the 50% of the population live within 1.5 km of the coast (Mimura et al., 2007).

Other risks SIDS face

While they can vary widely in geographical terms, SIDS share underlying economic, social, and environmental risks. Being so highly dependent on a small number of industries for GDP, especially tourism, leaves them vulnerable to reduction in GDP income if the cost of living on (or transport to) these islands becomes so high that it is unaffordable for tourists to visit. On the other hand, tourists seek the kind of untouched natural environment that will become increasingly rare if SIDS' most common environmental issues (such as reduced biodiversity, coral reef degradation, and chemical and nutrient pollution) persist (Mimura et al., 2007), which could further undermine earning potential from tourism and thus SIDS' abilities to be economically self-sufficient. Appropriate infrastructure would address these issues and help to ensure the near future of this industry, because although tourism may not turn out to be sustainable in the long run, for now it is such an important revenue stream that it must be protected as SIDS look to develop other industries to make themselves more resilient to external forces.

The tourism revenue stream is even more important now because SIDS are also facing considerable infrastructure costs as they mitigate and deal with the effects of climate change. The more intense tropical cyclones, flooding and storm surges, and sea level rise are likely to be among the most destructive and costly events, requiring significant investment in infrastructure to maintain SIDS populations against these changes (Mimura et al., 2007). In addition, SIDS are still often very dependent on subsistence agriculture, agricultural exports, and fisheries for their livelihood, and as they are currently operated, these areas are very likely to be adversely affected by climate change (Mimura et al., 2007). SIDS are usually dependent on expensive imported fertilisers to maintain their agricultural yields (for example, see Tongan Ministry of Finance and National Planning, 2008). A paradigm shift towards resilience-focussed agriculture and fisheries management will help to protect these sources of food and revenue, also avoiding the social risks inherent in poverty and food shortages.

However, the continual population loss experienced by many SIDS, especially those in the Pacific, presents a more immediate social risk. The average migration out of SIDS is 4.45 per 1000 people; this rises to 16.68 for the Pacific region alone (calculated from available data from CIA World Factbook, 2010b). This demographic loss gets much worse for SIDS in that it tends to be the more educated people who are leaving: the median emigration rate of tertiary educated people as a percentage of the total tertiary-educated population is 62.6%, with upper and lower quartiles at 26.9% and 78.2% respectively (calculated from available data from World Bank, 2010). If SIDS cannot retain their most educated people, they will have difficulty developing alternative industries to diversify their economies.

Environmental risks underpin many of the economic and social risks to SIDS. Climate change may be the most notorious environmental risk facing SIDS, but it is certainly not the only one. Freshwater scarcity continues to pose a problem for people dependent on rainfall and groundwater for their water supply, and saltwater intrusion into groundwater supplies may get even worse as sea level rises (Mimura et al., 2007). Freshwater lenses are also prone to faecal contamination because of inadequate sanitation practices (Menzies, 2005). Soil erosion due to modern farming techniques is impacting SIDS' agricultural potential, and beach erosion due to an increase in the number and intensity of storm surges and 'king tides' threatens housing, coastal infrastructure, and tourism resources (Mimura et al., 2007). Over-exploitation of fisheries has implications for the long-term viability of these resources and for the oceanic ecosystem (Kerr, 2005). One of the biggest and most harmful environmental problems on SIDS is waste management, as significantly more material comes into the country than leaves, which often results in solid waste being burned, buried in unsanitary conditions, or dumped, usually in lagoons or mangroves (Menzies, 2005). On many islands there is no space or infrastructure for sanitary landfills or recycling facilities, and even where landfills exist, shallow soils mean that freshwater lenses are very vulnerable to contamination (Mimura et al., 2007).

The question of whether SIDS should strive for sustainable development, then, is not difficult to answer. It is a question of the viability of continuing to live on these islands, and of the degree of self-sufficiency and quality of life for the inhabitants of SIDS.

Sustainable development

It has been suggested that sustainable development may be expressed in terms of resource depletion: that pollutant emission must not exceed the earth's assimilative capacity; the rate of use of renewable resources must not exceed their regeneration rate; and the rate of use of non-renewable resources must not exceed the rate at which renewable substitutes can be found (Barrett, Sexton and Green, 1999). More specifically, Baccini (1997) suggests that a system's "metabolism" is sustainable if the demand for essential 'mass goods' including water, biomass, construction materials, and energy, can be satisfied indigenously by more than 80% in the long term. Baccini notes that “the degree of self-sufficiency, arbitrarily chosen with respect to a set of essential goods, determines the ecologically-defined border of the (urban) system.” By this definition, sustainability requires that the demand for these essential goods which cannot be satisfied indigenously may be met by the ‘external market’ in such a way that the global resource capitals are not reduced significantly, so long as any emissions or other outputs are not burdens for future generations (Baccini, 1997).

With current shipping and air transport technologies, the latter would completely isolate SIDS from the outside world, but this does not seem like a fair or appropriate response. Neither do SIDS have the capability to develop sustainable transport technologies themselves; so for now, it makes sense to work towards sustainable development through Baccini’s first criterion, by sourcing at least 80% of mass goods locally. Baccini acknowledges that the figure of 80% may be chosen arbitrarily, as determined by the ecological boundary of the system. He also applies it solely to urban systems, so if this principle is to be applied to SIDS, it needs to be determined exactly what capacity for production each island has, and what demand for consumption.

Urban metabolism

Urban metabolism is a mass balance analysis applied to measuring the inputs and outputs of an urban system, usually water, energy, food or nutrients (Faerge, Magid, and Penning de Vries, 2001; Baker et al., 2001), materials (Hammer, Giljum, and Hinterberger, 2003), or a combination thereof (Baccini, 1997; Ngo and Pataki, 2008; and Sahely, Dudding, and Kennedy, 2003). Because urban metabolism is based on the mass balance principle, it could theoretically be applied to any bounded area, and the results would show an average of the “metabolism” of the bounded system: its consumption, production, and waste. As SIDS have easily defined geographic boundaries, urban metabolism may be a useful method of establishing these inputs and outputs, and thereby SIDS’ potential for sustainability. Combined with a physical needs analysis and GIS mapping, it may be possible to examine concentrations of resource flows and reveal underlying infrastructural requirements, enabling scenario planning for basic infrastructure to support sustainability (water supply, wastewater treatment, solid waste management, transportation, and energy supply).

If it is to be applied to SIDS in the context of sustainable development, urban metabolism is not without its own challenges. For example, re-exports (goods that are shipped to one location with the intention of shipping them on to another location) can contribute significantly to SIDS’ GDP but are not part of the indigenous metabolism, therefore it is not clear to which country’s metabolism the transportation of re-exported goods belongs. Similarly, tourism is an essential component of most SIDS’ economies, but due to SIDS’ remoteness their tourists travel a long distance (usually by air) to reach their destination. SIDS reap the benefits of this long-distance travel but it is not within their means to make this transport more efficient, so do the emissions and resources used belong to the SIDS or the tourists’ home countries? Finally, it is apparent that the availability of certain resources will change over the years, as will demand for resources. Changes that are likely and/or predicted include population increases, urbanisation, land use changes, and inundation of some areas as the sea level rises, and there will certainly be others. Any model developed using urban metabolism would have to be either dynamic or grounded in at least two temporal positions, to allow for predicted changes and comparison with the present situation.

Conclusion

To remain viable in the long-term, SIDS must become much more self-sufficient in supplying their populations with basic human needs by introducing sustainable agricultural, water supply, waste management, and energy systems, based on appropriate infrastructure. Infrastructure that supports sustainability is not only vital to maintaining and improving the quality of life of SIDS inhabitants; to conserve their vital income streams from tourism and fisheries revenues, SIDS will have to ensure that infrastructure is designed to preserve and encourage biodiversity and protect their environments from the impacts of overexploitation.

The principle of urban metabolism shows potential as a tool for indicating the needs and production capacities of SIDS, and therefore whether and how they can become self-sufficient. Used together with GIS, it may be possible to analyse both natural and anthropogenic consumption and production patterns, thereby revealing the characteristics and locations of infrastructure that would support sustainability on SIDS.

References

Baccini, P. (1997) "A city's metabolism: Towards the sustainable development of urban systems." *Journal of Urban Technology,* **4***(2),* 27-39.

Barrett, P. S., M. G. Sexton, and L. Green. (1999) "Integrated delivery systems for sustainable construction." *Building Research and Information*, **27***(6),* 397-404.

Baker, L. A., D. Hope, Y. Xu, J. Edmonds, and L. Lauver. (2001) "Nitrogen balance for the Central Arizona-Phoenix (CAP) ecosystem." *Ecosystems,* **4**, 582-602.

CIA World Factbook. (2010a) "Cape Verde: Economy. Economy – Overview." Retrieved from https://www.cia.gov/library/publications/the-world-factbook/geos/cv.html on 18 June 2010.

CIA World Factbook. (2010b) "The World Factbook." Data retrieved from https://www.cia.gov/library/publications/the-world-factbook/index.html on 11 June 2010.

Diamantopoulou, P. and K. Voudouris. (2008) "Optimization of water resources management using SWOT analysis: the case of Zakynthos Island, Ionian Sea, Greece." *Environmental Geology,* **54**, 197-211.

Færge, J., J. Magid and F. W. T. Penning de Vries. (2001) "Urban nutrient balance for Bangkok." *Ecological Modelling,* **139***(1),* 63-74.

Hammer, M., S. Giljum, and F. Hinterberger. (2003) "Material flow analysis of the city of Hamburg." Presented at the workshop Quo vadis MFA? Material Flow Analysis – Where Do We go? Issues, Trends and Perspectives of Rearch for Sustainable Resource Use, 9-10 October, Wuppertal.

Kerr, S. A. (2005) "What is small island sustainable development about?" *Ocean and Coastal Management,* **48***(7-8),* 503-524.

Krumdieck, S. and A. Hamm. (2009) "Strategic analysis methodology for energy systems with remote island case study." *Energy Policy,* **37***(9),* 3301-3313.

Liu, C.-W., C.-N. Lin, et al. (2006) "Sustainable groundwater management in Kinmen Island." *Hydrological Processes,* **20***(20),* 4363-4372.

Menzies, S. (2005) “Year of action against waste – special report: The true cost of Tonga’s waste.” SPREP. Available at http://www.sprep.org/article/news_detail.asp?id=214.

Mimura, N., L. Nurse, R. F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem. (2007) “Small islands.” *In:* Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Eds.). Cambridge University Press, Cambridge, UK, 687-716.

Ngo, N. S. and D. E. Pataki. (2008) “The energy and mass balance of Los Angeles county.” *Urban Ecosystems,* **11**, 121-139.

Sahely, H. R., S. Dudding, and C. A. Kennedy. (2003) “Estimating the urban metabolism of Canadian cities: Greater Toronto Area case study.” *Canadian Journal of Civil Engineering,* **30***(2)*, 468-483.

Smyth, A. J. and J. Dumanski. (1993) “FESLM: An international framework for evaluating sustainable land management.” World Soil Resources Report, Food and Agriculture Organization of the United Nations.

Tongan Ministry of Finance and National Planning. (2008) “Kingdom of Tonga annual foreign trade report for 2007.” Series number SDT: 31-28. Current publications available at http://www.spc.int/prism/tongatest/Publication/publication.htm.

UNDESA. (2003) “World statistics pocketbook: Small island developing states.” United Nations, New York.

UNDP. (2010) “Human development reports: 2009 report country factsheets (alphabetically).” Retrieved from http://hdr.undp.org/en/countries/alphabetical/ on 04 June 2010.

UN-OHRLLS. (2005) “Mauritius strategy for the further implementation of the programme of action for the sustainable development of small island developing states.” Port Louis, Mauritius, 10-14 January. Available at http://www.un.org/special-rep/ohrlls/sid/MIM/A-conf.207-crp.7-Mauritius%20Strategy%20paper.pdf.

UN-OHRLLS. (2010) “List of small island developing states.” Retrieved from http://www.un.org/special-rep/ohrlls/sid/list.htm on 26 May 2010.

Vince, G. (2009) “Paradise lost: Islanders prepare for the flood.” *New Scientist,* **2707**, 37-39.

Webb, A. P and P. S. Kerch. (2010) “The dynamic response of reef islands to sea-level rise: Evidence from multi-decadal analysis of island change in the Central Pacific.” *Global and Planetary Change,* **72***(3)*, 234-246.

World Bank. (2010) “The World Bank Data Catalog.” Data retrieved from http://data.worldbank.org/data-catalog on 17 June 2010.

Zukerman, W. (2010) “Shape-shifting islands defy sea-level rise.” *New Scientist,* **2763**, 10.