How many light globes does it take to change a footprint?

M. Lenzen[1] & P. Maganov[2]
[1]*ISA, School of Physics, University of Sydney, NSW, Australia*
[2]*Randwick City Council, NSW, Australia*

Abstract

This work covers two key areas related to ecological footprint analysis. The first section covers issues related to the calculation of ecological footprints for the populations of two Statistical Subdivisions (SSDs) and Statistical Local Areas (SLAs) of Eastern Sydney, Australia. These were obtained by applying input-output analysis to population and expenditure data from the 1998-99 Household Expenditure Survey and the 1996 and 2001 Australian Census carried out by the Australian Bureau of Statistics (ABS). The second section relates to linking results of the ecological footprint analysis to policy development, implementation and monitoring at a sub-regional level, namely the local government area of Randwick City in the Eastern Suburbs of Sydney, Australia.
Keywords: ecological footprint, input-output analysis, urban sustainability, environmental policy, resource consumption.

1 Introduction

The ecological footprint was originally conceived as a simple and elegant method for comparing the sustainability of resource use among different populations [1]. The consumption of these populations is converted into a single index: the land area that would be needed to sustain that population indefinitely. This area is then compared to the actual area of productive land that the given population inhabits, while the degree of "unsustainability" is calculated as the difference between available and required land. Unsustainable populations are simply populations with a higher ecological footprint than available land. Ecological footprints calculated according to this original method became important educational tools in highlighting the "unsustainability" of global

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consumption [2]. It was also proposed that ecological footprints could be used for policy design and planning [3, 4].

Since the formulation of the ecological footprint the concept has undergone significant modification and improvement [5–7], mostly in response to both observations and criticism levelled at the original concept by a number of researchers [8–14].

This presentation assumes there will be further refinement of the ecological footprint concept and calculation methodology. In the brief space permitted, there is an assumption of some acceptance of the ecological footprint methodology and its application to organisations, individuals and entities. While accepting that the ecological footprint concept has advantages and disadvantages this paper attempts to focus some discussion on the policy context of an ecological footprint calculation, particularly at a sub-regional setting.

The original ecological footprint represents the area of land required to meet the consumption needs of a population and the land needed to absorb all their waste [15]. In this approach, consumption is divided into 5 categories: food; housing; transportation; consumer goods; and services, while the land component is represented under 8 categories: energy land; degraded or built land; gardens; crop land; pastures and managed forests; and 'land of limited availability. This latter category is considered to include untouched forests and 'non-productive areas', which the originating researchers defined as deserts and ice-caps. Internal calculations remove so-called 'non-productive' areas from the overall ecological footprint analysis.

Over the past 30 years, an input-output approach has been applied in numerous ecological footprint calculation methodologies, and appears to provide a more robust approach for assessing environmental impacts of human populations. Since its first application to New Zealand, input-output analysis for ecological footprint analysis has grown continuously.

In 2003, this approach was applied to the ecological footprint calculation for the State of New South Wales (NSW) in Australia [16] for the purposes of that State's triennial State of the Environment Report [17]. More recently, a pilot study has been completed for the State of Victoria, also in Australia (www.epa.vic.gov.au/eco-footprint/docs/ vic_ecofootprint_demand.pdf). In both cases, calculations were undertaken using various methodologies to enable comparison and understanding of the differences between earlier methodologies and the application of input-output analysis. Input-output-based ecological footprints are considered to have a number of advantages: they do not incur artificial boundaries, they draw on detailed data sets that are collected regularly by government statistical agencies, and they can be calculated for industry sectors and product groups, for states, local areas and cities, as well as for companies and households. Finally, input-output-based ecological footprints allow valid trade-offs with other sustainability indicators, placing the ecological footprint within the broader context of a Triple Bottom Line (TBL) model or framework.

The main results table below summarises the results for the per-capita ecological footprint of all regions and years examined, based on both a *shared*

responsibility (both producer and consumer) and on a *full consumer responsibility*. The quantities shown are "total *impact*" (total ecological footprint per capita), and "total *intensity*" (ecological footprint per capita and per dollar of expenditure). Results are shown for the Statistical Subdivisions of Inner Sydney and the Eastern Suburbs. The categories "government administration" and "capital infrastructure" cover expenditures that are not made by final consumers themselves, but by the government and producers in order to provide the "commons", i.e. government administration and infrastructure such as buildings, roads, ports etc.

Note that Statistical Local Areas (SLAs) results for Randwick, Woollahra and Waverley are based on *estimated not surveyed* expenditure figures (see maps below). Results are therefore partly an effect of the regression estimation procedure and the explanatory variables used. Inner Sydney is listed for comparison. Finally, the benchmark is the average Australian consumer.

2 Regional and sub-regional areas covered

The Integrated Sustainability Analysis (ISA) group at the University of Sydney has assembled a framework for calculating ecological footprints tailored to Australian conditions. This framework employs the most detailed and comprehensive information on land distribution and greenhouse gas emissions available in Australia. The methodology uses comprehensive input-output tables prepared by the Australian Bureau of Statistics and CSIRO satellite-image based assessment of land disturbance over the Australian continent (significant truncation errors (often 25-50%) of upstream requirements that are common in conventional ecological footprint do not occur in the proposed methodology).

In 2003, this approach was used to calculate the ecological footprint of the State of NSW in Australia and for the Statistical Divisions making up Sydney's Greater Metropolitan Region (GMR) [18], The results were the first prepared specifically for and included in, the triennial NSW State of the Environment (SoE) Report [19] although the analysis carried out included other methodologies for comparative purposes [20]. While the main results were incorporated briefly in the NSW SoE Report, there was no attempt at considering the policy relevance or implications of the ecological footprint calculation in the NSW SoE Report.

In 2005, in order to assist Randwick City Council establish baseline information for the preparation of Randwick's 20-year City Plan [21], ISA also undertook Randwick's ecological footprint calculation. The analysis included not only the population of the Randwick Local Government Area, but a number of other Statistical Subdivisions (SSDs) and SLAs within the Eastern Suburbs of Sydney. To enable some understanding of potential differences across these areas and consider the potential implications within a policy context, two calculations were provided for each area: 1) a detailed component breakdown of the aggregate ecological footprint in terms of critical inputs and impacts, and 2) a short time series of the ecological footprint, in order to identify significant trends and changes.

Through this approach, results can be interpreted *ex-post*, as answers to the questions: "What the ecological footprint would have been assigned to the user's entity, given base year economic and resource use structure, and assuming proportionality between monetary and resource flows?" Results however cannot readily be interpreted in an *ex-ante*, predictive way, such as, "How would the ecological footprint change as a consequence of changes in the user's financial and resource flows?"

In the original ecological footprint method, the areas of forest, pasture and crop land do not represent real land, but hypothetical areas needed to support the consumption of the population, if local farming and forestry was conducted at 'world average productivity'. Proceeding as such makes it easy to compare ecological footprints of different countries or populations [22]. However, the loss in detail through the conversion to world-average productivity makes it impossible to use an ecological footprint for formulating regional policies, because the latter always involve region-specific economic, political, technological, environmental and climatic aspects [23].

In 2004, three committees set up by the Global Footprint Network aimed to resolve inconsistencies in methodologies through the development of standards for ecological footprint practitioners. A major difference from past methodologies was to separate out ecological footprint' components into final consumers and their upstream suppliers (in the commonly employed full consumer responsibility for ecological footprints, companies and industries must have an ecological footprint of zero by default). This separation enables a clearer representation of upstream 'producer' ecological footprints without double-counting in the ecological footprint of final consumers. Sharing responsibility holds for many situations in business and in life and acknowledges that there are always two (groups of) people who play a role in commodities produced and impacts caused, hence two perspectives involved in each transaction: the supplier's and the recipient's. Responsibility is shared between them, both in terms of benefits and burdens. Sharing each impact between the supplier and the recipient – for example on a 50-50 basis – alleviates the double-counting problem when ecological footprint between producers and consumers is calculated.

Bastianoni et al. [24], acknowledges an importance in this separation as "assuming [only] a consumer responsibility […], producers are not directly motivated to reduce emissions, while consumers, […] without adequate incentives or policies, […] are not likely to be sensitive with respect to their environmental responsibilities […]".

An interesting feature arising out of applying a shared responsibility between producer and final consumer is that the upstream responsibility for a given impact decreases with increasing distance between the various 'actors' in the supply chain. In this recent work, both shared and full consumer responsibility are applied and contrasted.

Table 1.

Ecological Footprint	Total impact		Total intensity	
	shared responsibility	full consumer responsibility	shared responsibility	full consumer responsibility
Randwick SLA 1996	2.69 ha	4.87 ha	2.84 m2/$	1.85 m2/$
Randwick SLA 2001	2.87 ha	5.30 ha	2.70 m2/$	1.68 m2/$
Woollahra SLA 1996	3.47 ha	6.47 ha	2.60 m2/$	1.70 m2/$
Woollahra SLA 2001	3.53 ha	6.66 ha	2.53 m2/$	1.57 m2/$
Waverley SLA 1996	3.16 ha	5.88 ha	2.49 m2/$	1.59 m2/$
Waverley SLA 2001	3.34 ha	6.32 ha	2.40 m2/$	1.44 m2/$
Eastern Suburbs SSD 1998	3.16 ha	5.97 ha	2.62 m2/$	1.46 m2/$
St George - Sutherland SSD 1998	3.08 ha	5.48 ha	3.10 m2/$	1.96 m2/$
Inner Sydney SLA 1996	3.16 ha	6.01 ha	2.64 m2/$	1.53 m2/$
Inner Sydney SSD 1998	3.00 ha	5.60 ha	2.61 m2/$	1.54 m2/$
Inner Sydney SLA 2001	3.54 ha	6.87 ha	2.52 m2/$	1.56 m2/$
Government administration	0.11 ha	0.34 ha	0.70 m2/$	0.59 m2/$
Capital infrastructure	0.57 ha	1.31 ha	1.80 m2/$	1.89 m2/$
Benchmark: average Australian consumer	2.04 ha	3.57 ha	3.53 m2/$	2.23 m2/$
Including government and infrastructure				
Randwick SLA 1996	3.37 ha	6.52 ha	3.88 m2/$	2.89 m2/$
Randwick SLA 2001	3.55 ha	6.95 ha	3.74 m2/$	2.72 m2/$
Woollahra SLA 1996	4.15 ha	8.12 ha	3.64 m2/$	2.74 m2/$
Woollahra SLA 2001	4.21 ha	8.31 ha	3.57 m2/$	2.61 m2/$
Waverley SLA 1996	3.84 ha	7.53 ha	3.53 m2/$	2.63 m2/$
Waverley SLA 2001	4.02 ha	7.97 ha	3.44 m2/$	2.48 m2/$
Eastern Suburbs SSD 1998	3.84 ha	7.62 ha	3.66 m2/$	2.50 m2/$
St George - Sutherland SSD 1998	3.76 ha	7.13 ha	4.14 m2/$	3.00 m2/$
Inner Sydney SLA 1996	3.84 ha	7.66 ha	3.68 m2/$	2.57 m2/$
Inner Sydney SSD 1998	3.68 ha	7.25 ha	3.65 m2/$	2.58 m2/$
Inner Sydney SLA 2001	4.22 ha	8.52 ha	3.56 m2/$	2.60 m2/$
Benchmark: average Australian consumer	2.72 ha	5.22 ha	4.57 m2/$	3.27 m2/$

3 Results highlights and summary

The following main results were established [25]:

1. The per-capita ecological footprint of Eastern Sydney is above that of the average Australian, no matter which calculation method is employed, and which year is appraised. This is most likely due to the greater affluence of households in Eastern Sydney, compared with the average Australian.
2. The per-capita ecological footprint of Eastern Sydney has increased between 1996 and 2001. This result is independent of inflation, which has been taken out of the figures. It is most likely due to increasing living standards. The percentage increase of the ecological footprint between 1996 and 2001 is highest for the Randwick SLA with a percentage increase of 6.6%.
3. The ecological footprint *intensity* (ecological footprint per dollar of expenditure) is low in areas with high ecological footprint, and high in areas with low ecological footprint. This is due to the fact that wealthy households purchase a larger proportion of services than less wealthy households. Since

services are associated with smaller ecological footprint intensity, the overall ecological footprint intensity of wealthier households is lower.

4. The per-capita ecological footprint for our commons (government and infrastructure) constitutes about 30% of the average Australian's per-capita ecological footprint, but only about 17% of the ecological footprint of Eastern Sydney residents. This result is due to the fact that the common components were allocated on a per-capita basis, i.e. an equal amount to each Australian.

5. The ecological footprint calculated based on shared responsibility is smaller than the ecological footprint calculated based on full consumer responsibility. This result is due to the fact that within shared responsibility, ecological footprints are shared between producers and consumers, and only a part of the responsibility is passed on to consumers. Shared responsibility recognises that Australian companies are capable of calculating their own ecological footprint: Also, within shared responsibility, the sum of all producers and consumers equals the total national ecological footprint. Within full consumer responsibility, the ecological footprint of any producer (company, industry sector etc) is zero.

6. Ecological footprint intensities calculated based on shared responsibility are higher than ecological footprint intensities calculated based on full consumer responsibility. This is due to the circumstance that within the household's consumption bundle, footprint-intensive commodities such as meat, electricity or petrol have their impacts in production stages that are relatively close to the final consumer. Considering that shared responsibility has an inherent feature of down-weighting ecological footprints that are caused in more remote production stages, and up-weighting ecological footprints in more proximate stages, this leads to an overall increase of the ecological footprint intensity compared to full consumer responsibility.

7. The ecological footprint of the average Australian consumer is lower at 5.22 ha/cap than a previously calculated value of 6.7 ha based on the 1994-95 input-output system. This is due to the fact that the previous figure included capital expenditure as intermediate and not final demand.

8. Most of the total ecological footprint is due to the land component, and not to greenhouse gas emissions.

4 Policy Response to Randwick's ecological footprint

Randwick's overall strategic priorities in terms of governance, social, environmental and economic planning and decision-making are set out in Council's recently completed 20-year City Plan. A major direction within City Plan includes the incorporation of the Melbourne Sustainability principles into established goals and objectives. This includes recognition of the need to

establish and reduce the ecological footprint of the Randwick Local Government Area (LGA), an area approximately 39 square kilometres.

To facilitate the capacity to achieve a reduction in the ecological footprint of Randwick City, a special environmental levy equivalent to 6% of the business and residential rate commenced from July 1, 2004 for a 5-year period. This levy, calculated to raise around Aus$2.4M each year, is for spending on specific environmental improvements and sustainability initiatives under Randwick's Sustaining our City Program. Being located approximately 8 kilometres from Sydney's Central Business District and with 29 kilometres of coast line including the Pacific Ocean and the historic eastern shores of Botany Bay, the Sustaining our City Program has a major coastal focus. The Program's 5 main thematic areas and budget streams include: Coastal Protection; Conserving Resources; Protecting Biodiversity; Tackling Greenhouse; and Community Participation.

Over the current financial year, staff have invested substantial effort in integrating the directions and outcomes in the 20-year City Plan into the annual business and management processes of Council's mandatory Management Plan. This ensures accountability of City Plan outcomes and Sustaining our City deliverables through the annual Management Plan. The Management Plan is placed on exhibition for Randwick's 120,000 residents and submitted to the NSW Minister for Local Government.

As well as a comprehensive strategic approach, various operational initiatives have commenced across each of the major themes of the Sustaining our City Program. A number are relevant and worth highlighting for the purpose of this discussion. For example, late in 2005, Council adopted a 20% voluntary reduction target for both water and energy consumed across Council. This action was taken ahead of Randwick completing mandatory Water Saving and Energy Saving Plans by March and September 2006, respectively. Council has ostensibly achieved its water reduction target and is close to achieving its energy reduction target.

On top of major improvements in water and energy management, Council is also required to achieve an overall waste reduction target of 14% within a statutory timeframe of 2014. These targets too are close to being achieved through improved mechanisms for kerbside recycling collection and the separation and processing of organic 'greenwaste'. Council's new Greenwaste Recycling facility is currently reprocessing around 95% of 100,000 tonnes of material received annually into 23 final products, most of these meeting stringent quality assurance standards before being sold on to bulk supplies and other local Councils. In addition, a 315,000 litre wastewater re-use system ensures potable water is used only for on-site drinking and showering purposes. A waste education classroom is being constructed on-site for small educational groups to visit the Greenwaste Recycling facility and through the environmental levy will incorporate rooftop solar power and underfloor rainwater storage systems.

Environmental levy projects have included construction of a major wastewater re-use system at the Council's main Depot which over its first 12 months of operation, has saved in the order of approximately 4 million litres of town water. At the Council's Community Nursery where native plants are

propagated from locally collected seed, a 40,000 litre underground stormwater re-use system is being installed to provide approximately 80% of the nursery's irrigation needs. Designs are underway to construct a 140,000 litre backwash water re-use system at Council's Aquatic Centre. Ten to twenty thousand litres of treated backwash water will be redirected through the Centre's toilet amenities with the remaining water to be used for irrigating adjacent parkland and for re-charging the groundwater of the Botany Sands aquifer under the parkland and pool area.

The investment in the environmental levy has also benefited Council and its ratepayers by attracting an additional Aus.$500,000 worth of funding to levy projects over the past 12 months alone, one of these includes funding to reinstate an indigenous 'bush tucker' trail on the eastern shores of historic Botany Bay.

Community efforts have been included in the Sustaining our City Program, for example, the distribution of 55,000 energy efficient globes, free to residents over a 3-month period. As well as saving an estimated Aus$2.4M from householder energy bills, the globes will also reduce greenhouse gases by approximately 5,500 tonnes over the life of the globes. A new energy incentive scheme for householders will see home and unit owners able to receive a free home energy audit with from June 2006, with follow-up financial incentives for a limited number of householders to install a range of energy saving measures including solar hotwater systems, solar panels and thermal insulation. A similar incentive is being investigated for Spring 2006, to top up the existing rainwater tank rebate on offer to householders from the State water utility. A rainwater tank offer has also been made to each of the 39 primary and secondary local schools in Randwick over the next 3 years.

Other programs for residents include free Sustainable Living workshops conducted on an ongoing basis through the local community college, a series of Open Days held at Council facilities to showcase projects underway or completed and an inaugural EcoLiving Fair held as part of World Environment Day in June. The focus of these events is to provide practical demonstrations, workshops and resources that lead to changes in householder behaviour and actions. A similar range of efforts is underway with local schools but progressing slower than anticipated due to existing curricula demands on schools. The first Sustainability Agreement between a university and local Council has been signed in Australia between Randwick Council and the nearby University of New South Wales to enable university access to operational and on-ground areas of learning but also provide Council access to relevant research and projects underway by both academics and students. The agreement has resulted in full semester learning projects where final year undergraduates take on sustainability-related Council projects.

While plans to revisit and update Randwick's ecological footprint are built into City Plan and Management Plan objectives, it will be just as important for Council to ensure its ongoing monitoring and reporting of results and continue to establish accurate changes in footprint outcomes. A number of major processes to achieve this are underway but aim to be built into staff performance and appraisal systems currently under review.

Further information on Randwick Council's Sustaining our City and environmental levy program can be obtained via Council's website at http://www.randwick.nsw.gov.au or by contacting either, Richard Wilson, Sustainability Communications Officer richard.wilson@randwick.nsw.gov.au or Peter Maganov, Manager, Sustainability, peter.maganov@randwick.nsw.gov.au or Team.Eco@randwick.nsw.gov.au

References

[1] Rees, W.E. Ecological footprints and appropriated carrying capacity: what urban economics leaves out. *Environment and Urbanization* **4(2)**, pp. 121-130, 1992.

[2] Costanza, R. The dynamics of the ecological footprint concept. *Ecological Economics* **32**, pp. 341-345, 2000.

[3] Wackernagel, M. Ranking the ecological footprint of nations, 1997. Internet site http://www.ecouncil.ac.cr/rio/focus/report/english/footprint/ranking.htm, Centro de Estudios para la Sustentabilidad.

[4] Wackernagel, M. and Silverstein J. Big things first: focusing on the scale imperative with the ecological footprint. *Ecological Economics* **32**, pp. 391-394, 2000.

[5] Bicknell, K.B., Ball R.J., Cullen R. and Bigsby H.R. New methodology for the ecological footprint with an application to the New Zealand economy. *Ecological Economics* **27(2)**, pp. 149-160, 1998.

[6] Simpson R W, Petroeschevsky A and Lowe I An ecological footprint analysis for Australia, *Australian Journal of Environmental Management* **7**, pp. 11-18, 2000.

[7] Lenzen, M. and Murray S.A. A modified ecological footprint method and its application to Australia. *Ecological Economics* **37(2)**, pp. 229-255, 2001.

[8] Levett R. Footprinting: a great step forward, but tread carefully, *Local Environment* **3 (1)**, pp. 67-74, 1998.

[9] van den Bergh, J.C.J.M. and Verbruggen H. Spatial sustainability, trade and indicators: an evaluation of the 'ecological footprint'. *Ecological Economics* **29(1)**, pp. 61-72, 1999.

[10] Ayres, R.U. Commentary on the utility of the ecological footprint concept. *Ecological Economics* **32**, pp. 347-349, 2000.

[11] Moffatt, I. Ecological footprints and sustainable development. *Ecological Economics* **32**, pp. 359-362, 2000.

[12] Opschoor, H. The ecological footprint: measuring rod or metaphor? *Ecological Economics* 32, pp. 363-365, 2000.

[13] Rapport, D.J. Ecological footprints and ecosystem health: complementary approaches to a sustainable future. *Ecological Economics* **32**, pp. 381-383, 2000.

[14] van Kooten, G.C. and Bulte E.H. The ecological footprint: useful science or politics? *Ecological Economics* **32**, pp. 385-389, 2000.

[15] Wackernagel, M. and Rees W. *Our Ecological Footprint: Reducing Human Impact on the Earth*. New Society Publishers Philadelphia, PA, USA, 1995.
[16] NSW EPA, The Ecological Footprint of the Sydney Greater Metropolitan Region and New South Wales (Report prepared by Dr Manfred Lenzen and Dr Sven Lundie, University of Sydney for the EPA), unpublished, Sydney, October 2002
[17] NSW EPA, State of the Environment Report, 2003, Environment Protection Authority, Sydney, 2000 Online. http://www.environment.nsw.gov.au/soe
[18] Lenzen, M., Lundie, S., Maganov, P., and Wachsmann, U. The Ecological Footprint of the Sydney Greater Metropolitan Region and New South Wales, (*unpublished*), 2004
[19] NSW EPA, State of the Environment Report, 2003, Environment Protection Authority, Sydney, 2003 Online http://www.environment.nsw.gov.au/soe
[20] NSW EPA, The Ecological Footprint of the Sydney Greater Metropolitan Region and New South Wales (Report prepared by Dr Manfred Lenzen and Dr Sven Lundie, University of Sydney for the EPA), unpublished, Sydney, October 2002
[21] Randwick City Council, Draft City Plan, Randwick , Sydney, 2005 Online http://www.randwick.nsw.gov.au/
[22] Wackernagel, M., Lewan L. and Hansson C.B. Evaluating the use of natural capital with the ecological footprint. *Ambio* **28(7)**, pp. 604-612, 1999
[23] Lenzen, M. and Murray S.A. A modified ecological footprint method and its application to Australia. *Ecological Economics* **37(2)**, pp. 229-255, 2001.
[24] Bastianoni, S., Pulselli F.M. and Tiezzi E. The problem of assigning responsibility for greenhouse gas emissions. *Ecological Economics* **49**, pp. 253-257, 2004.
[25] Lenzen, M. An Ecological Footprint study of Eastern Sydney, Result of consultancy work undertaken for Randwick Council, University of Sydney, January 2006.