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ANALYSIS

An assessment of environmental sustainability in Northern Australia using the ecological footprint and with reference to Indigenous populations and remoteness

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ABSTRACT

Nearly a third of the population of the Northern Territory of Australia is Indigenous and the Northern Territory environment has sustained Indigenous cultures for millennia. Under traditional management the land area used per person was relatively large but few resources were imported. Although the reliance on local resources has declined through interactions with Western society, at least some exploitation of the natural environment remains. This means that higher-density urban populations, which are largely non-Indigenous, have larger footprints than rural and remote populations, which are largely Indigenous. Thus Northern Territory urban populations are not necessarily requiring less land, but are just offsetting their land impacts to other regions. Finally, Indigenous ecological footprints are found to be heavily influenced by the provision of government services.

1. Introduction

A characteristic of the Northern Territory (NT) is the high proportion of Indigenous Australians. The granting of ownership rights to traditional lands in the 1970s, and provision of welfare payments, has helped maintain the capacity of many Indigenous people to retain elements of a subsistence lifestyle based on traditional harvest. Although both internal and external pressures are increasing for the full integration of Indigenous people into the market economy, substantial proportions of dietary intake in remote areas in northern Australia are acquired locally. This is unlike the urban centres, which rely almost entirely on imported food.

In his analysis of the economy of Indigenous communities in the Northern Territory, Altman (2000) identified three overlapping sectors: the market, the state and the customary. The main connection between Indigenous people and the market has, until recently, been sale of art, commercial wildlife harvesting and engagement with tourism and mining (Altman 2001, 2007). Increasingly, however, the potential is being seen for Indigenous people to be paid for provision of environmental services and their management of the natural environment (Luckert et al., 2007). This includes the offset of greenhouse gas emissions through reduction in savanna burning. We intimate that the consumptive capacity of the population must also be included in this market sector in order to reflect the flow of goods and resources brought in to Indigenous communities. The state sector of the Indigenous economy refers to both the provision of services and provision of welfare payments to the populations. The customary economy, also referred to as the

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non-market economy, is an integral part of Indigenous populations living traditional lifestyles where hunting, gathering and fishing are common place, and where land and habitat management are part of day to day lives.

In contrast to Indigenous people, most non-Indigenous people in the Northern Territory live in urban centres, particularly in and around the capital, Darwin. The economy is primarily resource-based with some tourism. Mining and cattle production are the principal industries with limited local value-adding, and there is heavy reliance on subsidies from southern Australian centres of industry and population (Garnett et al., 2008).

This paper is an attempt to benchmark the environmental impact of this economy with respect to the Indigenous and non-Indigenous population, and to analyse the changes occurring with increased market assimilation of Indigenous people. To provide a quantitative analysis of environmental impact, we compare assessments within the Territory population, and between this and other populations. To do so we have adopted a holistic approach that is able to capture not only the *direct* impact on the environment through on-site activities (such as land use and fossil fuel consumption), but also the *indirect* impacts that occur in the provision of goods and services to the population to be studied. Without such an approach, the concept of sustainability is lost through transferring responsibility for actions up the production chain to distant industry. In the case of Indigenous people, the opening up of communities to the broader world has increased their consumption and hence responsibility for environmental impacts imbued in the marketplace. The ecological footprint is used in this paper as an assessment of environmental impact to give a meaningful and communicable connection to land.

The Ecological Footprint is a method aimed at measuring and comparing the resource use and pollution of different populations. The consumption of populations is converted into a single index: the land area that represents the demand that a population places on the earth's bioproductivity in order to sustain itself indefinitely. More specifically, the Ecological Footprint is a measure of human demand on the bioproductive land area that is required to support the resource demands of a given population or specific activities. This includes the land area needed to provide biological resources (raw materials, food, timber, etc) as well as the (notional) area required to absorb the carbon dioxide emissions emitted due to the consumption patterns of its population. This land area is located both within and outside the borders of the region, and therefore the Ecological Footprint is an indicator for the impacts of consumption of the population wherever the products and services are produced. Ecological footprints calculated according to this original method became important educational tools in highlighting the unsustainability of global consumption (Costanza, 2000). It was also proposed that ecological footprints could be used for policy design and planning (Wackernagel et al., 1997; Wackernagel and Silverstein, 2000).

Since the method's conception, many researchers around the world have provided criticism and carried out significant modifications and improvements to the concept proposed. We refer the reader to the most recent papers discussing the issues (Kitzes et al., in press; Wiedmann, in press; Wiedmann et al., 2006; Ferng 2007; Lenzen et al., 2007; Turner et al., 2007; Wiedmann and Lenzen 2007; Wiedmann et al., 2007). The criticisms initially stemmed from the oversimplification in ecological footprints of the complex task of measuring sustainability of consumption, leading to comparisons among populations becoming meaningless (van den Bergh and Verbruggen, 1999). In addition, the aggregated form of the final ecological footprint made it difficult to understand the specific reasons for the unsustainability of the consumption of a given population (Rapport, 2000), and to formulate appropriate policy responses (Ayres, 2000; Moffatt, 2000; Opschoor 2000; van Kooten and Bulte 2000). The concept has undergone significant modification and improvement (Bicknell et al., 1998; Simpson et al., 2000; Lenzen and Murray, 2001; Hubacek and Giljum, 2003; Wiedmann et al., 2006; Turner and Lenzen et al., 2007; Carballo Penela and Sebastián Villasante, 2008) including the use of input–output analysis, the incorporation of "global hectares", and the inclusion of all types of land. Input–output-based Ecological Footprints, as employed in this paper, are complete in that they cover the supply chains of the entire upstream economy that ultimately enables the production of consumer items. Local technologies are normalised using yield and equivalence factors in order to relate consumption to the average productivity of all bioproductive hectares on earth.

This paper thus has two principal objectives. The first is to compare the ecological footprints of the Indigenous and non-Indigenous sectors of the population. This is done in the context of fluid policy frameworks that may increase pressures for urbanisation of remote communities because costs of provision to the remote communities are considered too high. The second objective is to target areas in which the ecological footprint of the Territory population could most readily be reduced. The ecological footprint brings home locally responsibility for global impact in a way that is less easily contested than greenhouse gas production in that much of the gas production in a resource-based economy is undertaken for consumers elsewhere.

2. Method

2.1. *Input–output analysis — calculation of market and state EF*

The concept of the hybrid economy (Altman, 2000) is used to understand the implications of sustainability. The first two types of economy – market and state – can be assessed within the input–output framework. By doing so, we are providing a holistic assessment of the upstream requirements of the consumption of market-based goods, and the provision of government services. Hence, we define y_m as the market basket of goods and services consumed within the market economy by the population, and y_g as the provision of government goods and services to the population. Both are expressed in AUD$ per capita, and are expressed in *basic prices*[1].

[1] The concept of basic prices is an important delineation when modelling physical flows. Basic prices refer to prices without margins such as retail and transport included. This gives a more realistic and stable analysis of impact, due to the exclusion of price fluctuations.

Using input–output analysis, the upstream requirements of a bundle of final demand are calculated according to the Leontief Inverse (Leontief, 1966):

$$x = (I - \mathbf{A})^{-1}\left(\boldsymbol{y}_{\mathrm{m}} + \boldsymbol{y}_{\mathrm{g}}\right)$$

where x is the total requirements, $\mathbf{A}$ is the coefficient or technology matrix — a mathematical description of the goods and service flows between industries within an economy, and $\mathbf{y}$ is the vector of consumption. This can then be generalised to include the physical requirements of the economy, by including a vector Q of resource use by industry:

$$\boldsymbol{Q}_{\mathrm{EF}} = \boldsymbol{Q}_{\mathrm{EF}}^{\mathrm{ind}}(I - \mathbf{A})^{-1}\left(\boldsymbol{y}_{\mathrm{m}} + \boldsymbol{y}_{\mathrm{g}}\right)\boldsymbol{Q}_{\mathrm{EF}}^{\mathrm{hh}}$$

where Q_{EF} is the total ecological footprint, Q_{EF}^{ind} is the resource requirements expressed in global hectares of each industry within the economy, and Q_{EF}^{hh} is the household or on-site footprint impacts. For data sources, see Appendix A.

Input–output analysis has been chosen as the basis of the calculations due to its comprehensive and detailed covering of all upstream impacts flowing to consumption. National input–output tables have been used, as most goods and services consumed within the Northern Territory are brought in from elsewhere in Australia. Hence the relative value of margins is the main point of diversion, and specific data is included for this. Differences from electricity generation (NT uses gas or diesel compared to Black coal in the majority of Australia) are also factored in, as discussed below in Section 2.2.3.1.

2.2. Consumption data

Whilst production data is taken from a generalised Australian input–output database (see Appendix A), the estimation of the consumption vectors present a significant challenge, particularly when delineating indigenous consumption and remoteness effects. There is a paucity of data on the expenditure of Aboriginal people, identified earlier in (Smith, 1991b), and this is a significant challenge of this work. Household expenditure data by state is published by the ABS (Australian Bureau of Statistics, 2006b), but there is no separate identifier for Indigenous people — in fact, Indigenous and very remote communities are actually excluded in the statistics provided for the Northern Territory. In order to proceed, demographic data was collated by remoteness class such that a delineation could be made between populations included in the Northern Territory Household Expenditure Survey (HES) and populations excluded. The process applied in this work followed four main steps. i. A multiple regression was used to estimate the consumption basket (see Appendix B). ii. An optimisation of the consumption basket across the six categories against aggregate and detailed household expenditure data was performed. iii. Items of known expenditure (including electricity use), and price indices (estimated according to remoteness in order to include increased margins in remote communities) were included explicitly. iv. Expenditure was related to income, and used as an overall constraint on consumption.

2.2.1. Remoteness classes

Demographic data is available by remoteness class for Indigenous and non-Indigenous Australians in the Northern Territory from the ABS publication *Population Characteristics, Aboriginal and Torres Strait Islander Australians* (Australian Bureau of Statistics, 2001b). There are five remoteness classes, of which only three apply to the NT — "outer regional" (which only includes Darwin), "remote" (including outer Darwin, Katherine and Alice Springs) and "very remote" (balance of NT) (Australian Bureau of Statistics, 2001a; Bureau of Transport and Regional Economics, 2007). As this classification provides us with the best delineation of demographic variables at the Indigenous versus non-Indigenous level, we henceforth apply our analysis at this level. To reduce confusion for the context of the Territory, from this point, "outer regional" is referred to as Darwin, "remote" as Regional (capitalised) and "very remote" as Remote (capitalised).

2.2.2. Estimating market baskets of goods and services

The estimation of the vectors of consumption was conducted in three concurrent ways. Constraints were defined as more aggregated sets or subsets of data that were used to scale estimates. Hence by constraining data, we are forcing our estimates to match the aggregated data sets. Firstly, demographic data was used to give an initial estimate using the regression analysis (Appendix B), and later as a constraint on the data. HES data was also used to constrain the Darwin and Regional populations. Finally, explicit consumption data was used to constrain the initial estimates on very remote communities, and environmentally sensitive commodities such as electricity were included explicitly.

The demographic data provides a starting point for which to estimate consumption. In work done by Lenzen (see for example Lenzen et al., 2008) on estimating expenditure patterns for ecological footprint calculations at a local government level, demographic drivers have been used in a multi-stage regression in order to give an initial estimate to the consumption basket. In that work, significant and non-correlated demographic variables were found to be: income; household size; age; qualification; population density; tenure type; employment; country of birth; car ownership and transit means; dwelling type; age. The demographic variables were extracted from the ABS publication 4713.0 (Australian Bureau of Statistics, 2001b), and the subsequent consumption basket was estimated. From this data, non-Remote regions could be constrained by household expenditure data mapped to input–output classifications (HES data is available at a detailed level only for urban and regional areas).

The total household expenditure in the N.T. (including Remote) could be constrained by the State based National Accounts data (Household final consumption expenditure) for the NT, but this path has not been chosen for two reasons. The first is the high proportion of net expenditure interstate of households in the NT which is not categorised and could skew final consumption data from household expenditure data. The second reason is that this method does not distinguish between Indigenous and non-Indigenous consumption, which is a key focus of the study.

An alternate approach is to further combine the more detailed demographic data on Indigenous and non-Indigenous populations with the household expenditure data by demographic variable. Whilst the HES by demographic variable is more aggregated than the detailed state total HES data, it does

provide a method to balance the data to available constraints simultaneously. In essence, this is a system of demand equations that are balanced using linear least squares optimisation techniques. It should be remembered that this HES data still excludes Remote communities.

The system to be balanced this way includes the two non-Remote Indigenous classifications and the two non-Remote non-Indigenous classifications. There are twenty demographic variables common to the Indigenous survey and the HES data. Thus the system is over-determined with twenty equations of four unknown variables. The HES data has 13 different categories of consumption — hence, in total, we have a system of 13*4 variables. There was an obvious discordance between the HES and Indigenous survey, as, being over-determined, the system was not solved for any consumption category. Our balanced system was 23% closer to the constraints than the initial estimate, i.e. the optimisation provided a 23% improvement relative to the HES data over pre-optimisation values.

2.2.3. *Explicit items*

A number of consumption items were estimated explicitly due to either the importance in the overall footprint, or the availability of data.

2.2.3.1. Electricity and on-site emissions. Electricity supply in the major centres is primarily from Natural Gas. Regional communities generally rely on diesel generators, although renewables are being introduced. The Australian Greenhouse Office publishes estimates of the indirect emissions from electricity supply as part of its Australian Greenhouse Emissions Information System. In 2004, for the Northern Territory, this amounted to 278.31 Gg CO_2-equivalent. This figure was redistributed on a per-capita basis to remoteness classes by the estimated expenditure on electricity from the regression analysis, and finally converted to units of global hectares using carbon dioxide equivalence factors. A similar process was done directly for remote aboriginal communities, where the total electricity supply was known directly (91 GWh (Power and Water Corporation, 2006) and was converted to CO_2 equivalence using the AGO statistics on (Australian Greenhouse Office, 2006) emission factors for diesel generators.

Emissions from transport and non-transport residential activities (such as cooking with gas) were also estimated. Total figures in the Northern Territory of 371.52 Gg CO_2-eq for transport activities and 26.4 Gg CO_2-eq for non-transport activities (Australian Greenhouse Office, 2007) are apportioned by estimated petroleum use and other fuel use by remoteness class for the transport and non-transport activities respectively.

2.2.3.2. Price indices. It is widely acknowledged that the consumption of goods and services throughout the Northern Territory, and particularly in remote communities, are affected by higher than average retail and transport margins. The margins have the effect of changing the size of the ecological impact embodied in the dollar value paid for consumer items, principally due to the vast distances and smaller populations. For example, a kilo of (non-local) produce purchased in a remote community has required more transport, with corresponding greenhouse emissions, than a kilo of produce bought nearer supply centres – but an additional cost is paid, such that for every dollar spent, there is a smaller quantity of produce received in remote communities – which transfers to a lower ecological footprint embodied in a dollar of consumption. In order to equalise these effects, the value of the margins must be estimated. Using price indices of the Australian capital cities (Australian Bureau of Statistics, 2007), and the surveyed price indices of a market basket of goods in different regions of the Northern Territory (Territory Health Service, 2004), it is possible to estimate the prices paid throughout the Territory relative to the Australian average. Whilst a higher level of product detail was used in the calculation, the average margin on all goods in Darwin was 8% greater than the national city average. Remote and Regional stores were 27% greater than Darwin and Remote stores were close to 20% greater than Regional stores (Territory Health Service, 2004). Thus, once adjusted to the national average, final indices averaged across all goods are 1.08, 1.25 and 1.50 for Darwin, Regional and Remote regions respectively. Expenditure levels of commodities were hence reduced by these indices, reallocating the expenditure to the Transport and Retail Trade sectors.

In remote stores, whilst freight might be assumed to be a significant expense, a survey of cost structures in remote aboriginal stores (McDonnell and Martin, 2002) found freight costs to be equivalent to 3.8% of total sales, or 12.5% of total retail expenses. Hence the additional margins were allocated accordingly.

2.2.3.3. Remote expenditure breakdown. In a review of literature, Aboriginal expenditure on food ranges from 33 to 65% of total expenditure, with a range of studies finding 50–55% expenditure in remote communities (Smith 1991a). Of this expenditure, roughly 36% was spent on meat, 23% on bread and cereals and 23% on sugar based products. Remaining expenditure was allocated according to either explicit data available for tobacco and alcohol consumption and outlined above, or via the regression.

2.2.3.4. Saving. Initial estimates were such that levels of expenditure were greater than levels of income. Whilst this is possible if savings or credit is used to fund current expenditure, experience shows that savings in Indigenous communities are relatively low (Musharbash, 2001 p 56; Senior et al., 2002).

In wider terms, gross disposable income in the Northern Territory for 2003–4 was $6250m, with household final consumption expenditure ($5953m (Australian Bureau of Statistics, 2006c). This equates to an expenditure to income ratio of 0.975, which signifies that the majority of income is expended on goods and services within the current financial year, with only 2.5% of income saved. Under the assumption that all saving occurs in non-Indigenous populations, this expenditure to income ratio becomes 0.971 for the non-Indigenous population.

2.3. *Estimating state expenditure*

Both the Federal and the Territory Governments publish estimates on Indigenous related expenditure across all departments. From this data, it is possible to discern general Indigenous related expenditure as well as specific expenditure for health, education,

Table 1 – Ratio of Indigenous to Non-Indigenous government expenditure

Health	2.66
Education	1.54
Justice	2.93
Primary industry	0.90
Total	1.46

justice and primary industries. Other demarcations by sector are possible, but less clear, and due to the relatively small amounts of expenditure attracted, are not important in this analysis.

As a first step, for Territory expenditure, the average per-capita expenditure was calculated for Indigenous people, and subsequently for non-Indigenous people, across the sectors listed above. Concurrently, the average government expenditure for all Australian's was calculated from National Accounts/Input–Output data. Aggregate national accounts data distinguish state and federal expenditures. Thus, average Federal government expenditures across the range of sectors was estimated according to these aggregates. Subsequently, Federal expenditures were added to Territory expenditure figures. This process was necessary in order to obtain reliable estimates of Territory based expenditure on the population, compared to average expenditures across all states.

Final estimates of the ratios of Indigenous to Non-Indigenous expenditures are shown in Table 1.

For comparison, the national average of the ratio of expenditure on health is 1.22 (ABS 4704.0), including private services, and 1.68 excluding private services. The difference is intuitive, however, due to the significantly higher expenditure in the Territory, compared with other states (State Government expenditure is a ratio of 2.8 — ABS 4704.0 Table 2). Further data on expenditure by remoteness is available from the AIHW (Australian Institute of Health and Welfare, 2005). For Indigenous Australians, Regional and Remote expenditure (bundled) is 1.52 times outer regional expenditure, on a per-capita basis. For non-Indigenous Australians, this ratio is 0.84.

2.3.1. *Housing*

The provision of housing in Indigenous communities has required significant government support, and hence needs to be addressed separately. Average weekly rent collected for Indigenous housing in NT is $31/week for State housing (Australian Institute of Health and Welfare, 2007). Continuing expenditure is available from the ABS (Australian Bureau of Statistics, 2006d). Recurrent expenditure to capital is 0.61 for state housing in NT (Australian Institute of Health and Welfare, 2007). Government expenditure was estimated from a range of statistics — most separating Indigenous and non-Indigenous expenditure, but only limited data could be correlated to the remoteness indices.

2.4. *The customary economy impacts*

The third sector of the hybrid economy – the customary economy – is challenging to integrate into the analysis, mainly due to the lack of robust data. In the case of non-Indigenous Australians, the economy is assumed to be minimal, with non-significant impacts. It is less clear for Indigenous populations for which the customary economy takes up a significant proportion of everyday life. The paucity of recent data on sustainability of hunting and gathering to the Indigenous economy makes it untenable to include in this

Table 2 – Top ranked Footprint drivers

Rank	Indigenous Darwin	Regional	Remote
1	Residential — transport	Retail trade	Retail trade
2	Electricity supply	Residential — transport	Government resid bldg construction
3	Retail trade	Electricity supply	Government beef cattle
4	Fresh meat	Resid bldg construction	Government federal government
5	Meat products	Government resid bldg construction	Other food products
6	Government resid bldg construction	LPG, LNG	Government non-building construction
7	Resid bldg construction	Government beef cattle	Residential — transport
8	Government beef cattle	Fresh meat	Government non-resid building construction
9	Other food products	Government resid bldg repair and maintenance	Government education
10	Government federal government	Government federal government	Government wheat

Rank	Non-Indigenous Darwin	Regional	Remote
1	Resid bldg construction	Retail trade	Retail trade
2	Retail trade	Resid bldg construction	Air transport
3	Residential — transport	Residential — transport	Electricity supply
4	Fresh meat	Electricity supply	Residential — transport
5	Electricity supply	Fresh meat	Road freight
6	Meat products	Meat products	Resid bldg construction
7	Hotels, clubs, restaurants and cafes	Government beef cattle	Electronic equipment
8	Other food products	Hotels, clubs, restaurants and cafes	Government beef cattle
9	Government beef cattle	Road freight	Hotels, clubs, restaurants and cafes
10	Government non-building construction	Other food products	Fresh meat

analysis. However, where the connection to land remains uninterrupted, we assume that these customary activities are having no net impact, at least in the modern sense of sustainability. There is certainly some evidence that resources sold into the market economy arising from customary land use (art products, wildlife) are extracted sustainably (Griffiths et al., 2005; Koenig et al., 2005; Gorman et al., 2006). Thus, while the area of land over which customary activity is being undertaken may be relatively large, it is assumed that removal of resources takes place at a rate commensurate with their natural replacement. Where the practice of custom now involves use of recent technology (e.g. fuel and vehicles to go hunting), we assume these costs will be included in statistics available for the market-based economy.

3. Results

3.1. *Overall footprint size*

The total footprint of the population of the Northern Territory is approximately 1.6 million global hectares, which, due to its small population and large land area, is just over 1% over the Territory's land area. The average per-capita footprint was estimated at 8.3 gha. Fifty-four percent of this is due to the non-Indigenous population of Darwin, and about 79% due to the non-Indigenous population across the Territory. For comparison, the non-Indigenous population of Darwin is about 48% of the population, and non-Indigenous population across the territory is about 69% of the total population (see Fig. 1).

Results across the board show a lower footprint for the Indigenous population (Fig. 2). About 50% of the Indigenous footprint was due to the personal consumption of the population, with the remaining 50% imbued in the provision of government services and other public expenditure. In comparison, over 75% of the non-Indigenous footprint was from personal consumption.

Populations in remote areas have lower footprints — principally due to their lower levels of personal consumption. The Government footprint is slightly higher in remote

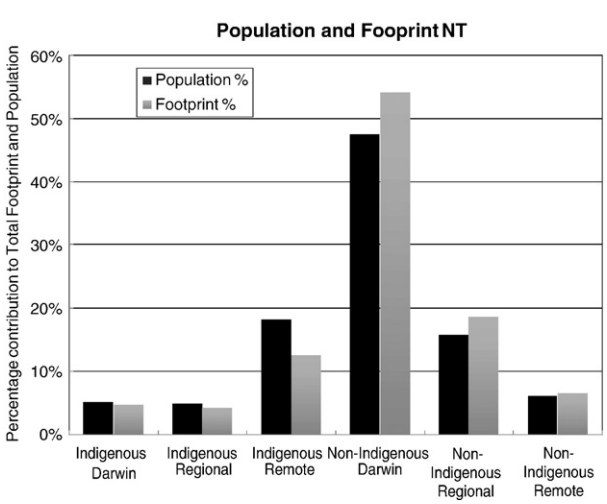

Fig. 1 – Comparison of population size to footprint size, by indigenous status, remoteness class.

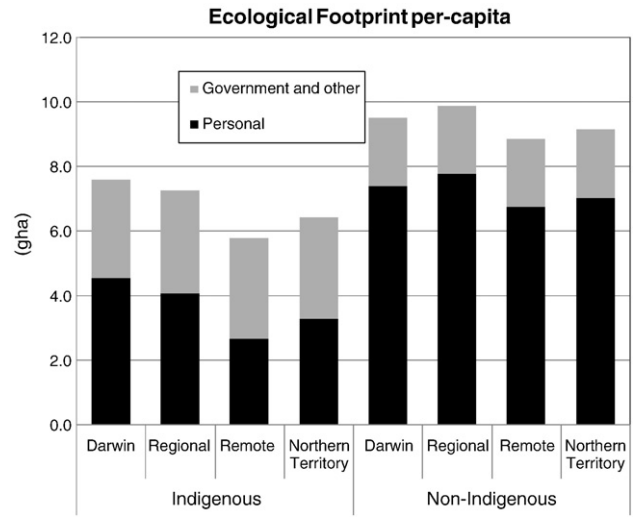

Fig. 2 – Per-capita Ecological Footprint (gha/capita) by indigenous status and remoteness class.

Indigenous communities — reflecting the extra environmental costs of service provision to remote areas. This gap may be underestimated, due to the lack of data across some expenditure items by remoteness class — particularly housing, education and general government services.

3.2. *Footprint by consumption category*

The breakdown of the total footprint into consumption categories (Fig. 3) shows the dominance of the footprint embodied in service provision — ranging between 23 and 37% of overall footprints. Included in this category are trade margins, with associated transport impacts. Food and mobility footprints are also high — reflecting the large impacts of meat production and the large distances travelled by the

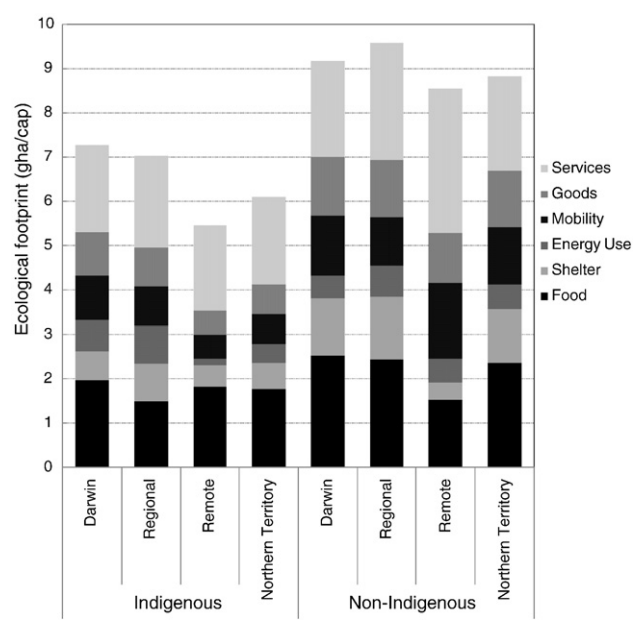

Fig. 3 – Ecological Footprint per capita by indigenous status and remoteness class by consumption category.

population within the Northern Territory, and in flights. A more detailed investigation of the top drivers of these categories is given in the next section.

3.3. *The top drivers*

It is clear that we have a disparity between the ecological footprint of different Indigenous and remoteness classes, and between the people of the Northern Territory and the globally equitable level. In order to address these issues we provide a more detailed investigation into the top drivers of the footprints by region. By doing this, we can help identify "essential" services as opposed to non-essential services. Data at this level of detail is subject to a higher level of uncertainty than aggregate data, hence it is most useful as an approximate guide to major impacts rather than definitive ranking.

Consistently, the top ranked impacts occur from transport, retail trade and construction. Goods and services provision (shown through retail trade) to regional and remote communities are the top ranked impact for both Indigenous and non-Indigenous populations. The challenge is to maintain this service for small communities whilst reducing the magnitude of these impacts. The distance required to be covered in the transport of often small amounts of goods and services is the main problem. Increasing consumption of locally grown goods and local service provision would be the obvious first step in achieving this. Residential building construction is also highly ranked, reflecting the growth in the population of the Territory. Electricity supply, meat consumption and residential transport are the other main drivers of the footprints.

4. Discussion

The average ecological footprint of people in the Northern Territory is about four times higher than the global average of 2.2 gha and 25% higher than the Australian average of 6.6 gha (Global Footprint Network, 2006). Within the Northern Territory, remote Indigenous people have the lowest footprint and Indigenous people as a whole have lower footprints than non-Indigenous people. In remote areas in particular this is likely to be because Indigenous people continue to obtain a substantial proportion of their sustenance sustainably from the land on which they live, thus not entering the footprint accounts. However, the more Indigenous people become part of the urban economy, the greater their footprint. Even so, urban Indigenous people have a footprint substantially smaller than any of the non-Indigenous sectors of the population.

A substantial proportion of this difference can be attributed to Indigenous poverty. The average income of Indigenous people in the Northern Territory is approximately 40% that of non-Indigenous people. The greatest challenge of achieving sustainability is to be able to move towards low environmental impacts whilst simultaneously improving quality of living. The obvious difference of the footprint between the Indigenous and non-Indigenous populations is the intensity of government services. In economic terms, this is showing that the social security system is working, with higher expenditure per person on the poorer sections of the population. However, from a sustainability point of view, this comes at an ecological cost, and it will be a challenge for policy makers to decrease the magnitude of this government footprint whilst providing the required services.

One possible means by which this can be achieved is investment in Indigenous natural resource management (Luckert et al., 2007). This investment has the potential to increase income and decrease the need for government services by improving health, increasing social function and raising the proportion of food and other materials obtained from the land (Garnett and Sithole, 2007). There is also the opportunity for active management of the land to reduce the ecological footprint by offsetting greenhouse gas production elsewhere. While it is not yet possible to account for this reinvestment in ecological services using ecological footprint analysis, the payments for active management of fire by Indigenous people to reduce greenhouse gas production currently being rolled out across remote northern Australia could be interpreted as a credit against the debit of their consumption.

Overall there is a footprint of approximately 8.3 ha per person in the Northern Territory, roughly 25% higher than the national average. Reducing the ecological footprint, however, is something to which there could be political aspirations, especially in the Northern Territory where so much of the footprint is in the form of government services. More efficient and effective delivery of these services, a laudable fiscal and political objective, can thus have ecological and social benefits. As a first step, with appropriate government regulations and constraints, parity to the national average is easily within political reach.

In conclusion, this paper has sought to provide a picture of sustainability of the Northern Territory by estimating the population's ecological footprint by Indigenous status and remoteness class. In general urban populations have larger footprints than remote populations, non-Indigenous populations have larger footprints than Indigenous populations. This supports the notion that higher-density urban populations are not necessarily requiring less land, but are simply offsetting their land impacts to other regions.

Appendix A. Data sources — model

In the compilation of the generalised input–output framework, it was necessary to confront and reconcile data sets documented according to the Australian and New Zealand Standard Industrial Classification (ANZSIC), the Input–Output Product Classification (IOPC), the Australian land use (ALUMC) classification, the Household Expenditure Survey commodity classification, and the reporting format prescribed by the Intergovernmental Panel on Climate Change (IPCC).

Surveys of industries, households and farms are not conducted in identical intervals. Hence, the input–output, household expenditure, resource use and pollution data refer to different years between 1998 and 2003. In order to minimise discrepancies, input–output and factor data was assembled for years closely around 1998–99, where data availability was best. Data were reconciled using RAS matrix balancing (see Junius and Oosterhaven, 2003), and optimisation techniques (see Tarancon and Del Rio, 2005). As a consequence, small

flows (monetary and physical) are associated with large uncertainties.

The household expenditure matrix **Y** was derived from the most recent 2003–04 Household Expenditure Survey (Australian Bureau of Statistics, 2006a), while the direct requirements matrix **A** was constructed from the Australian input–output tables (Australian Bureau of Statistics, 1999a,b; see also Lenzen, 2001).

The industrial ecological footprint multipliers Q_{ef}^{ind} as well as household ecological footprint multipliers Q_{ef}^{hh} were obtained by consulting a range of sources such as fuel statistics (Australian Bureau of Agricultural and Resource Economics, 1999, 2000). The Australian National Greenhouse Gas Inventory (Australian Greenhouse Office, 1999; George Wilkenfeld & Associates Pty Ltd and Energy Strategies, 2002), the ABS' Integrated Regional Database (Australian Bureau of Statistics, 2001c), and a CSIRO report on landcover disturbance across the Australian continent (Graetz et al., 1995); (Lenzen and Murray, 2001).

Appendix B. Multiple regression

The multiple regression employed in this work follows the work established by Lenzen (see for example, Lenzen et al. (in press) for a more detailed explanation). We include a summary description of the process in this appendix. Multiple regression seeks to establish the relationship between the explained variable y of household expenditure, and a number of explanatory variables x_i. The explanatory variables initially included were:

- annual per-capita before-tax household income,
- number of household members,
- index of highest qualification of household members aged 15 and over with a qualification,
- index of house type,
- population density in people per km^2,
- average age,
- percentage of household members aged 18 and below,
- percentage of household members aged 18–64 working,
- provenance: percentage of people in region born overseas, tenure type,
- car ownership (cars per person),
- percentage of people travelling to work by car

Using multiple regression, and taking into account the varying sample sizes of the Household Expenditure Survey sample groups (and resulting heteroskedasticity), the expenditure on the expenditure items was estimated from explanatory variables sourced from the census data pertaining to the regions examined. A stepwise multiple regression was followed, consisting of

- establishing correlation coefficients between the expenditure of samples on each of the 344 commodities, and all explanatory variables, starting with commodity 1;
- selecting the variable with the highest correlation coefficient as the first regression variable;
- selecting the variable with the next highest correlation coefficient as the second regression variable, and so on;
- calculating an adjusted R^2 value for each subsequent regression, and checking whether the adjusted R^2 increases more than 0.1%;
- if not, terminating the addition of further explanatory variables to the regression model, and moving on to the next commodity.

This stepwise regression procedure is data-driven, as opposed to the theory-driven hierarchical multiple regression, where a model is specified based on purely theoretical considerations. The stepwise procedure was used because it is preferred if the purpose of regression is simple prediction of expenditure (Cramer, 1969), and because a sound theoretical reason for a dependence of the consumption of a particular commodity on socio-demographic–economic variables can in general not be established *a priori*.

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