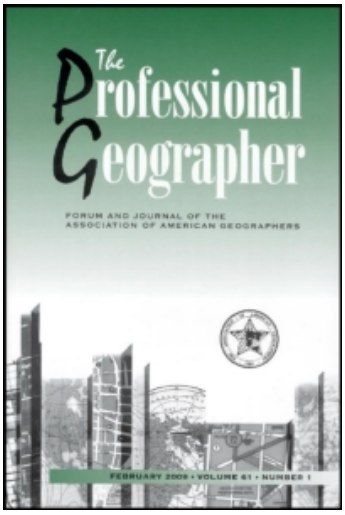


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# Connecting Local to Global: Geographic Information Systems and Ecological Footprints as Tools for Sustainability

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# Connecting Local to Global: Geographic Information Systems and Ecological Footprints as Tools for Sustainability*

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Tools that support public engagement with sustainability are essential for local sustainability planning. This research investigates the ability of two geographic information system (GIS)-based tools to promote discussion of sustainability in a suburban context. A local ecological footprint tool and a community environmental atlas (an environmentally themed online mapping system) were created for seven suburban boroughs of Montreal. Variations of both tools have been used to support sustainability efforts, but their use has not been widely evaluated. Working from a public participation GIS (PPGIS) framework that recognizes the powerful influence of data representation, this research uses focus groups to evaluate how well these tools address three criteria that have emerged from the literature on public engagement in sustainability: interdependency across systems, reflexivity about personal and social decision making, and interactions across spatial scales. Whereas the atlas remains advantageous for discussing local spatial specifics, it was found that the ecological footprint helped people see the interconnections among systems, integrate local and global aspects of sustainability, and reflect on the values and assumptions underlying current social and economic structures. **Key Words: ecological footprint, geographic information systems, public participation, suburban, sustainability.**

对于当地的可持续发展规划，能够支持公众持续性参与的工具是至关重要的。本研究调查了两个基于地理信息系统(GIS)的工具的能力，以促进城市郊区可持续发展方面的讨论。在蒙特利尔市的 7 个郊区镇，建立了一个分析当地生态足迹的工具和一个社区环境图集（环保为主题的在线地图系统）。这两个工具的演变版本已被用于支持可持续发展的努力，但其使用效果还没有得到广泛的评价。基于公众参与的地理信息系统(PPGIS)的工作框架，承认数据表达的强大影响力，本研究利用了专题小组来评估这些工具在三个标准上的表现，这些标准是基于有关公众参与的可持续性方面的文献：跨系统的依赖性，关于个人和社会决策的自反特性，跨空间尺度的互动作用。我们认为，图集仍然有利于讨论局部空间的特性，研究表明，生态足迹有助于人们了解系统之间的相互联系，整合当地和全球各方面的可持续发展性，并有助于反映当前社会和经济结构下的价值观和预设前提。**关键词：生态足迹，地理信息系统，公众参与，郊区，可持续性。**

Las herramientas que concuerden con el compromiso público por la sostenibilidad son esenciales para la planeación local de la sostenibilidad. Esta investigación explora la capacidad de dos herramientas basadas en sistemas de información geográfica (SIG) para promover la discusión sobre sostenibilidad en un contexto suburbano. Una herramienta local de huella ecológica y un atlas ambiental de la comunidad (sistema de mapeo en red etiquetado ambientalmente) fueron creados para siete barrios suburbanos de Montreal. Algunas variantes de ambas herramientas se han utilizado para ayudar en esfuerzos de sostenibilidad, pero tal uso no ha sido suficientemente evaluado. Trabajando en un marco SIG de participación pública (PPGIS) que reconoce la poderosa influencia de la representación de los datos, esta investigación utiliza grupos focales para evaluar

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qué tan bien estas herramientas responden a tres criterios que han surgido de la literatura sobre el compromiso público en sostenibilidad: interdependencia entre sistemas, reflexibilidad acerca de la toma personal y social de decisiones, e interacciones a través de escalas espaciales. A la vez que el atlas sigue siendo ventajoso para la discusión de especificidades espaciales locales, se descubrió que la huella ecológica ayudaba a la gente a ver las interconexiones entre sistemas, integrar aspectos locales y globales de la sostenibilidad, y reflexionar sobre los valores y supuestos que subrayan las actuales estructuras sociales y económicas. **Palabras clave: huella ecológica, sistemas de información geográfica, participación pública, suburbano, sostenibilidad.**



Calls to promote sustainability in local planning are widespread (United Nations Committee on Environment and Development 1992; Satterthwaite and Earthscan 1999; Barton 2000; United Nations 2001; International Council for Local Environmental Initiatives 2002; Haughton and Hunter 2003; Roseland 2005) but it is clearly easier said than done. Geographic information systems (GIS) offer technologies that help, in part, by including decision support for public engagement in sustainability. Building on ecological footprint analysis (EFA) and research on public participation GIS (PPGIS), we developed two community-level GIS-based tools—an environmental atlas and an ecological footprint model—and evaluated their ability to support public engagement in discussions of sustainability. Variations on both tools have been widely applied, but their effectiveness has not been examined in a comparative context. Working from a PPGIS framework, which recognizes the importance not just of public access to data, but also of the powerful influence of data representation, we compared the two tools in supporting effective public engagement with discussions of sustainability.

Sustainability is a notoriously problematic concept due to its inherent ambiguities and contradictions (Basiago 1995; Pezzoli 1997; O'Riordan and Voisey 1998; Robinson 2004). Although a full review of the strands and nuances of the diverse literature on sustainablility is beyond the intent of this article, we argue in what follows that three themes cut across this discussion and are crucial to sustainability: interconnections across systems, reflection on societal values and patterns, and integration of scales.

The traditional three-pillar paradigm of sustainability based on the economic, sociocultural, and environmental dimensions has been criticized for treating each pillar independently and promoting trade-offs among them (Gibson and Hassan 2005; Pope 2006). Instead, as Gibson (2006) declares "the genius of the sustainability concept is its insistence on interconnections and interdependencies" (266), we suggest that integration across systems is essential to sustainability. Sustainability involves not only understanding that human choices have economic, environmental, and societal impacts but that these realms are intimately interconnected. Tools designed to promote public participation in sustainability must expose salient interconnections.

*Reflexivity* is used here to describe the process of reflecting on implicit values, conventions, and contradictions. For some, the utility of the concept of sustainability "lies precisely in the degree to which it brings to the surface contradictions and provides a kind of discursive playing field in which they can be debated" (Robinson 2004, 382). Similarly, O'Riordan and Voisey's (1998) concept of revelation argues that sustainability requires broad public engagement with the basic values that underlie conventional, unsustainable patterns. The process of identifying and grappling with these tensions becomes an important element of effective public engagement. We suggest that reflexivity demands that tools help reveal the values underlying (un)sustainability and encourage reflection on both personal decision making and the social context of such decisions.

*Integration of scales* presents practical and theoretical challenges that are endemic in discussions of sustainability. Berke and Conroy (2000) showed that a majority of local sustainability plans in the global north emphasized local, immediate concerns and excluded issues such as global ecological connections. This extends, for example, to the parochialism of "not in my back yardism" (NIMBYism) absent recognition of extralocal determinants or cosmetic local initiatives undertaken in the name of sustainability. In an attempt to mitigate such results, the concept of integration across scales has emerged as a key concept in sustainability—as characterized by the common phrase, "Think global, act local."

In a context of considerable debate about the concept of scale (Smith 1993; Swyngedouw 1997, 2004; Cox 1998; Marston 2000; Marston, Jones, and Woodward 2005; Leitner and Miller 2007), we suggest that although integration across scale implies hierarchical scales, there are efforts to reduce the tendency to either fix scales or privilege some scales over others. For example, attention has been paid to the importance and risks of communication strategies that address individual agency in the face of global processes. Such work has stressed that we need to recognize both our immediate and distant limitations and abilities and the connections between them to engage with sustainability in a way that is meaningful and yet does not lead to disempowerment (Hinchcliffe 1996; Macnaghten and Jacobs 1997; Bickerstaff, Simmons, and Pidgeon 2007). Similarly, work focused on understanding networks of resource flows can be seen as an attempt to capture various spatialities and to privilege place as well as space in the discussion of the mechanics of sustainability (Hansson and Wackernagel 1999; Wheeler 2000).

In these examples scale is not a fixed, strictly hierarchical concept. Instead, they emphasize the process of how actions in one particular place impact other particular or generic places and vice versa. We argue for tools that facilitate the recognition of this back-and-forth process. Sustainability tools must allow for discussion of the physical and temporally remote impacts of personal decisions but also recognize distal influences on personal decisions and impacts.

Mindful of these three sustainability criteria, two GIS-based tools were developed. The first was a community-level environmental atlas and the second was an ecological footprint tool. Both were designed to communicate sustainability in the seven western suburban boroughs of Montreal and were evaluated through the use of community focus groups. These communities are collectively known as the West Island and have been undergoing extensive changes in political structure, urbanization, and environmental planning. These changes have triggered local interest in environmental decision making and provided a useful location in which these tools could be meaningfully evaluated. This next section examines tool development from a participatory and decision-making perspective. The third section introduces the tools; the fourth describes the focus group methodology; and the fifth presents the results of this process. A final section discusses the implications of each tool's ability to support public engagement with sustainability.

## Discourses on Tool Development

There has been considerable effort to understand the use of GIS in public participation in policymaking (Talen 2000; Jankowski and Nyerges 2001a; Craig, Harris, and Weiner 2002; Elwood and Ghose 2004; Sieber 2006; Ghose 2007) and specifically in environmental and sustainability planning (Kellogg 1999; Harrison and Haklay 2002; Sieber 2002). These and other authors have found that GIS offers a critical political resource because representations of spatial data influence how we understand and communicate our context and what knowledge and experiences are likely to be formalized, accepted, and acknowledged (Harris and Weiner 1998; Elwood and Leitner 2003; Elwood 2006). Instead of reinforcing a single expert vision, PPGIS tools can enable community members to coproduce knowledge that varies from the official version and construct alternate visions of their environment (Ball 2002, 126; Elwood and Leitner 2003; Elwood 2006). These features suggest that PPGIS might respond particularly well to the three dimension of sustainability discussed earlier.

Geographical scale is particularly important in PPGIS because a direct relationship exists between the scale of data and the way that people conceive of space (Carver 2003). The larger the detail, the more likely people will relate to spatially localized issues, such as property values or local government. The smaller the detail—for example, a watershed—the more likely they will consider issues at a regional or global scale. Scale is unavoidable in GIS and reinforces elements of a spatial hierarchy. Even PPGIS can effect a "fixing" of scale (Ghose 2007) that reinforces a specific bounded geography, whether local or global, with prime explanatory power for sustainability. This is balanced by the priority placed by PPGIS on bottom-up agency and can be reduced by creating tools that encourage participants to explore linkages among scales.

Tool design was furthered by a review of the spatial decision support (SDSS) literature.

Our tools bear resemblance to SDSSs in that both address complex problems with ill-defined and uncertain solutions and conflicting interests and differing comprehension of the participants (Densham 1991; Jankowski and Nyerges 2001b). The task in SDSS is to create interactive tools that assist users in identifying alternatives; unlike our tools, SDSS emphasizes discrete sets of rules. SDSS research looks to increasing the number and range of participants and incorporating their diverse objectives, better integrating decision support methods, and supporting interdisciplinary data access and addressing technical issues; for example, improving user interface design, handling large data sets, and providing for semantic interoperability (Feick and Hall 1999; Jankowski and Nyerges 2001a; Ascough et al. 2002; Haklay and Tobón 2003; Rinner 2003). We are guided by these varied initiatives.

## Descriptions of the Two Tools

To explore the use of GIS tools to enable participation in local sustainability, we developed two tools, an environmental atlas and a tool using EFA. The environmental atlas was similar to many land-use-based GIS applications commonly used to support local participation in local planning and featured a simplified graphical user interface (GUI; Figure 1). It incorporated fourteen geospatial data sets that had both local and global implications for sustainability (Table 1). For instance, transportation is a local issue that also has global impacts on resource use and greenhouse gas emissions. In the atlas, transportation was represented through road, public transit (bus and commuter trains), and bicycle networks. This spatially oriented representation was echoed in the other data layers. On the question of scale, data ranged from the very local (city block size) to the political and physical boundaries of the West Island—which is crisscrossed by specific streets, parks, land-use zones, and boroughs. As much as possible, data themes and richness were matched for both tools. For some themes the match could not be achieved. For instance, Montreal's waste is taken off-island to landfills, making waste difficult to include in the atlas, although easily captured by the ecological footprint.

When presenting the atlas, the moderator oriented participants by indicating landmarks. Additional layers were then explored and participants were encouraged to interact with the GIS. Most found the tool interesting and easy to understand. As one participant commented, "It is really good to see your own community from this different perspective." Participants did not engage in significant data analysis nor did they formally weigh decision alternatives. They pointed out landmarks, made minor changes such as altering display colors, and turned certain map layers on or off; they also made suggestions as to the causes and the potential solutions to any sustainability problems they perceived.

We chose to compare traditional GIS applications to a tool utilizing EFA (Figure 2). EFA translates resource consumption into an aggregate metric of land (expressed as global hectares per capita, or GHPC). It has been widely used for communicating sustainability (Onisto, Krause, and Wackernagel 1998; Best Foot Forward 1999; Roy and Caird 2001; Barrett et al. 2004; Anielski Management 2005; Hunter, Carmichael, and Pangbourne 2006) because it is built on recognizing the connections across social, economic, and environmental systems and integrating global ecological impacts with individual consumption patterns (Wackernagel and Rees 1996). Although EFA has been criticized for its inability to accurately reflect the dynamism of ecosystems (Deutsch et al. 2000), aggregation of impacts (van den Bergh and Verbruggen 1999; van Kooten and Bulte 2000), and simplistic treatment of trade (van den Bergh and Verbruggen 1999), even fervent critics have defended its value for public engagement (Costanza 2000; Deutsch et al. 2000; Troell et al. 2001).

The tool used the component method of EFA (Chambers, Simmons, and Wackernagel 2000; Simmons, Chambers, and Barrett 2000) and contained nineteen variables, or components, that covered a wide range of actions with impacts for sustainability at multiple scales (Klinsky, Sieber, and Meredith 2009).[1] The footprint tool (hereafter simply referred to as footprint) is specific to the chosen areal unit, in this case the borough. Unlike the atlas, which stressed the physical locations of variables, the footprint represented the impacts of consumption at the level of the borough. For example, transportation variables included the vehicle kilometers traveled (VKT) by different modes, which was then translated

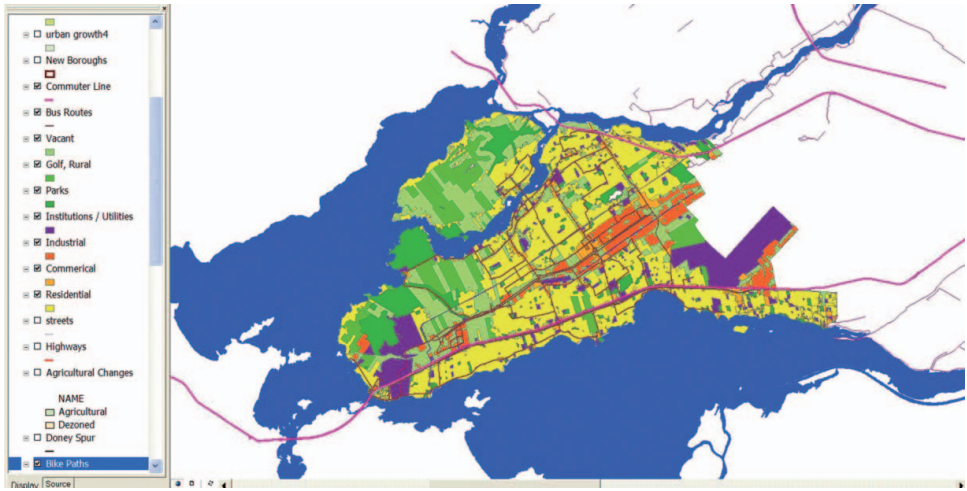


**Figure 1** *Screenshot showing public transit and zoning data included in environmental atlas.*

into GHPC. Although data were bound by political boundaries, the use of GHPC integrated diffuse or otherwise invisible global impacts such as contributions to carbon emissions. The specific GHPC value for each component was calculated for each borough, and these data were stored as spatial attributes of boroughs. A choropleth layer was created to represent each footprint.

Traditionally, representations of the EFA featured either numerical values or graphs, or pictures of multiple planet Earths. By using the ArcScene extension of ESRI's ArcMap footprints were shown as extruded 3D images specific to each borough. Component extrusions could be cumulatively "stacked" so participants could see the contribution of each. A semitransparent layer allowed participants to distinguish between components. Figure 2 shows the images viewed by participants. The first panel shows the total contribution of all transportation variables for each borough; the second shows the total per capita footprint for each borough; and the third shows transportation in the opaque layer with the total footprint in the shadow layer. The EFA was introduced to the participants layer by layer so that the contribution of each could be integrated.

Explaining the EFA took approximately ten minutes. A few participants were confused. For example, one participant asked again, "What does that height represent? Units, units? What are the units of that height?" But people generally responded to the tools with an enthusiastic "Wow, oh wow," or "It's crazy!" As with atlas groups, participants were encouraged to engage with the tool but actual interactions tended to be limited to requests to revisit particular components or to tilt the image so that a footprint of one borough could more easily be seen. The tool, however, elicited a variety of solutions or actions regarding sustainability issues.

## Focus Group Method and Analysis

The tools were evaluated in focus groups. Focus groups are not intended to be statistically representative (Merton 1987; Frankland and Bloor 1999; Kreuger and Casey 2000) but to be reflective. Focus groups have been used to examine environmental perceptions (Darier and Schüle 1999; Kasemir et al. 2000; Stoll-Kleeman, O'Riordan, and Jaeger 2001; Michael, Green, and Farquhar 2006; Bickerstaff, Simmons, and Pidgeon 2007) because they facilitate the observation of idea development in a social setting (Burgess, Limb, and Harrison 1988; Myers and Macnaghten 1999), trigger discussions about local specifics, and minimize interviewer

***Table 1*** *List of data layers and sources by theme and for each tool*

| | Ecological footprint | | Environmental atlas | |
|---|---|---|---|---|
| **Theme** | **Data layer** | **Data source** | **Data layer** | **Data source** |
| Transportation | VKT private vehicles | L'Agence Metropolitaine de Transport (1998) | Highway network | Statistics Canada (1996) |
| | | Haider (2003) | Street network | Statistics Canada (1996) |
| | VKT bus | L'Agence Metropolitaine de Transport (1998) | Commuter train routes | DMTI Spatial[a] (2001) |
| | | Haider (2003) | West Island bus routes | Statistics Canada (1996) |
| | VKT train | Statistics Canada (2000) | Bike paths | MUC (1996) |
| | VKT airplane | Statistics Canada (2002b) | Proposed commuter train extension[b] | MUC (1996) |
| | | | Proposed road development (de Salaberry and 440) | Statistics Canada (1996) |
| Energy | Residential electricity use | CREEDAC (2000) | | |
| | | Ville de Montréal (2004) | | |
| | Residential natural gas use | CREEDAC (2000) | | |
| | | Ville de Montréal (2004) | | |
| Waste | Household waste (landfilled) | RIGDIM (2000) | | |
| | Inert waste | RIGDIM (2000) | | |
| | Commercial waste | RIGDIM (2000) | | |
| | Recycled waste | RIGDIM (2000) | | |
| | Compost | RIGDIM (2000) | | |
| Food consumption | Food consumption | Statistics Canada (2002b) | Agricultural zoning changes | Statistics Canada (1996) |
| | Food equivalence factor | Statistics Canada (2002a) | | |
| | | Chambers, Simmons, and Wackernagel (2000) | | |
| Land use | Built land | MUC (2000) | Urban growth patterns from 1932 to 1991 | Shi (1997) |
| | | | Municipal zoning | MUC (1996) |
| | | | Parks | MUC (1996) |
| | | | Forest cover | DMTI Spatial (2001) |
| Other | Water consumption | Ville de Montréal (2002) | Old borough boundaries | MUC (1996) |
| | Forest product consumption | Forest Products Association of Canada (2002) | New borough boundaries | Ville de Montréal (2003) |
| | Rail freight | Statistics Canada (2000) | | |

*Notes:* MUC = Municipalitiés de la Communauté Urbaine de Montreal [Montreal Urban Community]; VKT = vehicle kilometers traveled.
[a]DMTI Spatial is a company specializing in digital geospatial data for Canada.
[b]The Doney Spur is an unused rail line. Local environmental groups are lobbying to have it turned into an additional commuter train line.

influence (Burgess 1996; Hoggart, Lees, and Davies 2002). We chose focus groups to simulate discussions and decisions made in a public policy setting. Increasingly, these tools are developed as Internet applications (Rinner 2003) but we decided against evaluating individual interactions with a Web-based platform. Carver et al. (2001) found that Web-based geospatial

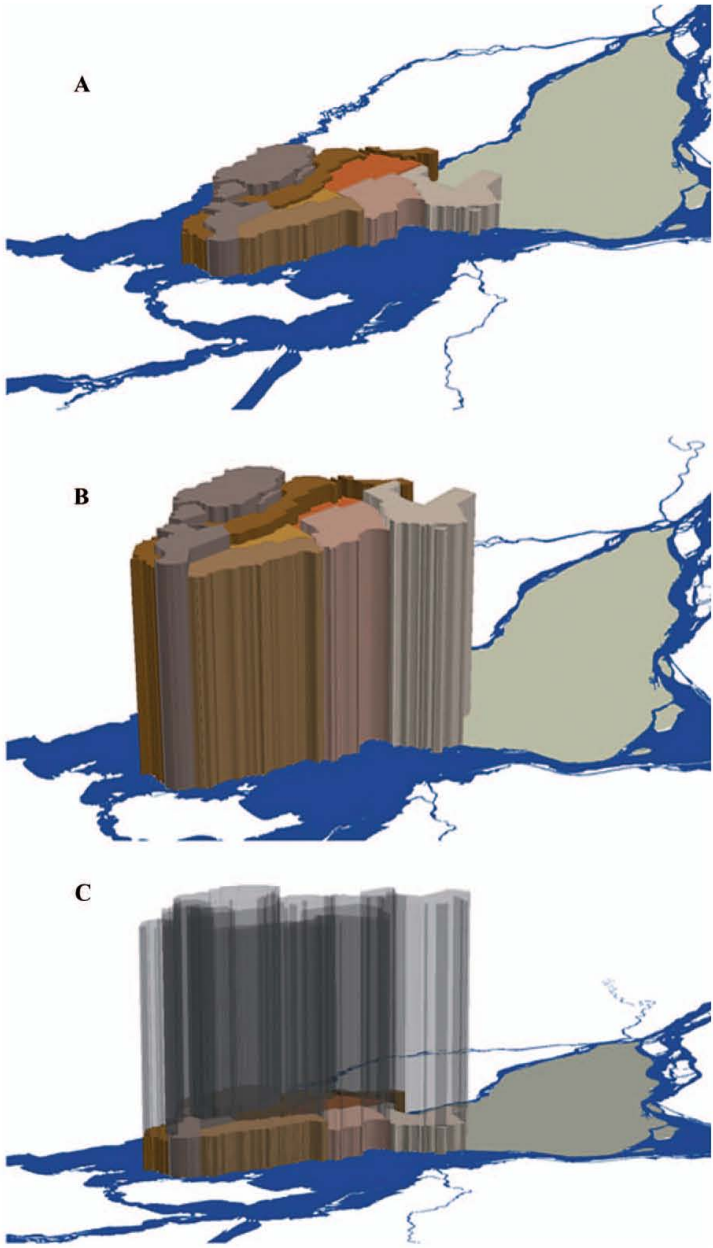


**Figure 2** *(A) Transportation component of the per capita ecological footprint by borough. (B) Total per capita ecological footprint per borough. (C) Transportation per capita contribution to ecological footprint in opaque layer with total per capita ecological footprint in shadow layer.*

tools cannot substitute for traditional planning approaches like group meetings. We were guided by calls that tools employing participatory methods should not be viewed as distinct from the collaborative and local settings in which they are deployed. Our hope was to put the place (physicality) back into space (of GIS).

Eight groups were created, each consisting of between four and six West Island residents from within existing community groups (Holbrook and Jackson 1996; Kitzinger and Farquar 1999). The groups contained more women than men and reflected the largely white, linguistically mixed, middle-class composition of the West Island.

Groups were recruited in pairs and one was assigned to each tool. Participants were given a prequestionnaire based on the new ecological paradigm (Dunlap et al. 2000). No significant differences were detected across the eight groups; average group scores were comparable to averages generated from random sampling within North America (Schultz and Zelezny 1999; Kotchen and Reiling 2000) and suggested slight pro-ecological attitudes (Rideout et al. 2005).

Moderator notes, verbatim transcripts, and flip chart notes were analyzed using a combination of thematic coding to identify conversation themes and discourse analysis, which focused on specific wording and interactions among participants (Klinsky 2004). Thematic coding was conducted using the qualitative data analysis software QSR N6. A combination of researcher-constructed and emic codes were developed through iterative rounds of coding and rethinking data (Glasner and Strauss 1967; Coffey, Holbrook, and Atkminson 1996; Buston 1997).

Each session took approximately two hours, divided into three periods (akin to Krygier's [2002] settings). In an introductory period, the moderator presented the research project and participants were encouraged to talk freely about their communities. The second period was semistructured and featured either the footprint or the atlas. Discussions during this period were used to illustrate influences of the tools. In the final period, the moderator used a flip chart to synthesize the discussions. A prepared list of potential community priorities was used on the flip chart to support intergroup comparability and provided an opportunity to discuss topics that had not emerged spontaneously. Each period served a specific function: The first contextualized discourse on the community, the second focused on sustainability discourse induced by the tool, and the last standardized the sustainability discourse across groups.

Discussions in the first period also established a baseline across groups. All focus groups shared similar social and environmental concerns, focusing on friendly neighborhoods and recreational opportunities, accessibility to shops and services, and the availability of and threat to green space. Discussions in the second period were compared by data themes and the importance of the theme (Table 2). Issues were coded as primary when group members discussed the topic at length, asked to see data represented in other ways, or introduced information. Issues coded as secondary were those considered only incidentally or by few participants. Tertiary conversations were stimulated only by the use of the flip chart at the end of each session. Blanks in Table 2 indicate themes not addressed by participants.

## Results

Transportation was important for both atlas and footprint groups, land use was prominent for atlas groups, and waste management was a critical issue for footprint groups (Table 2). A discussion of the ability of the two tools to support recognition of the interconnectedness of economic, social, and environmental systems; integration across scales; and reflexivity with respect to underlying values and assumptions is presented next.

### *Transportation*

Transportation was the only issue discussed broadly in all groups (Table 2). Conversations differed in content between tool-using groups but were similar in terms of time and attention.

*Atlas* In focus groups using the atlas, concerns with traffic gridlock, safety, and public transit dominated discussions of transportation. The following text is representative:

*Jane:* The [Highway] 30 they are building on the south shore? They should actually build one for trucks only. The trucks on these roads are destroying the highways.
*Kim:* Yeah.
*Mai:* They do.
*Jane:* They take the whole area of a car.
*Mai:* Yeah, safety issues.

***Table 2*** *Summary of topics discussed during the use of tools and flip chart*

| | Transportation | Land use | Waste | Food/agriculture | Water consumption | Energy |
|---|---|---|---|---|---|---|
| Environmental atlas focus groups | | | | | | |
| 1 | ●●● | ●●● | ● | | | ● |
| 2 | ●●● | ●●● | ●● | ● | ● | |
| 3 | ●●● | ●●● | ● | | | ● |
| 4 | ●●● | ●●● | ●●● | ● | | |
| Ecological footprint focus groups | | | | | | |
| 1 | ●●● | | ●●● | ●● | ● | ● |
| 2 | ●●● | ●● | ●● | ●●● | | |
| 3 | ●●● | ●● | ●●● | ● | | |
| 4 | ●●● | ● | ●●● | ●● | ●●● | ●● |

*Notes:* ●●● = central to tool discussion; ●● = included in tool discussion; ● = mentioned only in period three with prompting from flip chart.



*Jane:* It's very dangerous, oh god, there was one tipped over during the week and it blocked traffic for hours.

*Kim:* The whole system though, I mean it is archaic. You used to be able to go downtown in 20 minutes.

*Mai:* Not enough for 4 million people.

*Kim:* For sure.

*Jane:* But they should have highways, or tell them they [trucks] can only access travel during the night.

This particular discussion illustrates concerns surrounding transportation and actions for resolving these concerns. Participants suggested that government—the level of government was rarely specified in focus groups—should impose regulations to improve transportation. Replicated in all atlas groups, this reasoning defines transportation as a local spatial and technical problem amenable to government intervention.

Problems and actions were routinely grounded in local experience. Participants often referred to particular bus routes such as "If you go from [the borough of] Pointe Claire to the Metro [grocery store], the 203 [bus] doesn't stop right beside it; you have to walk." Members of three of four atlas groups reflected that the West Island is underserved by buses or trains. Existing public transportation was "designed to move people between the West Island and downtown Montreal" and lack of intracommunity transportation was perceived to be a key problem. One atlas group connected discussions of public transit explicitly to responsibility. As one participant argued, "[If] they don't want us to take the cars in then give us some functionality." Reducing car dependency therefore represented a prerogative of government instead of a duty of participants.

Atlas discussions highlighted locally specific issues and personal experiences of transportation options but did not consider broader ecological ramifications of transportation choices, larger cultural patterns, or integration across scales. Responsibility remained tied to governmental technical actions, not to individual choice.

*Footprint* Conversations about transportation in footprint groups were similar to those in atlas groups in both time and attention but participants used the footprint concept to discuss the impacts of transportation modes and to mark differences among boroughs. For example, long after transportation had been displayed and participants were weighing the prioritization of items on the flip chart, one woman returned to the tool and said "Car usage is one of the main issues." Components of the transportation footprint made participants realize the interconnectedness of transportation modes.

*Maude:* But even [the borough of] Beaconsfield [has commuter train stops] and look at how high [the ecological footprint] still is.

*Sarah:* It's because they want to drive their cars . . .

*Kristin:* A lot of people there do use public transit, but a lot of them don't.

*Sarah:* The thing about Beaconsfield, though, they seem more green than anybody though.
*Moderator:* In which way?
*Sarah:* Well, they banned the pesticides already; they are into composting.
*Kristin:* But they also have the money to afford the cars.

Participants noted that a community with relatively good public transit still generated high usage of private vehicles and they recognized that economic patterns were also related. Another group extended the discussion of transportation to debate the global ramifications of increased use of private vehicles, particularly in China. While expressing concerns about the growth of car dependency globally, they also questioned, "Why do we have the right to own three cars and they none?"

Participants also recognized the behavioral aspect of transportation and made statements such as "They are just in love with their cars," or recognized the connections between driving and societal patterns of time use, such as the demands created by work expectations. As one participant said, "Carpooling used to work when offices opened at nine and closed at five but now they have flex time; people have to work overtime." This behavioral perspective on transportation problems was echoed in potential actions offered by groups. Participants in all four footprint groups argued that the extent of change necessitated cultural adaptation. For example:

*Alain:* People are going to have to walk. You can't have an efficient system with a bus that stops on every street. But if you have a bus that goes on major thoroughfares at regular intervals then you have to exert more [personal energy] to get to that bus. Then if people don't have that mentality. . . . It is mentality that changes everything.

Walking was one of a wide variety of individual behavior-driven transportation solutions that also included moving closer to one's workplace, daily schedule planning to facilitate walking, biking, using a car cooperative, or working regular hours to ease ride sharing. Government played a role in taxation to discourage car use. As one member succinctly put it, "The solution is at the pump. It is more expensive to buy a liter of water than a liter of gas at the station right now."

Transportation in these conversations was highly interconnected with other issues—ecological and social. In addition to the technical infrastructure elements of transportation planning, participants widely recognized that transportation also was engrained in cultural and behavioral norms and in individual decision making. Linkages to issues such as the growth of car dependency in China and other developing countries demonstrated the tool's ability to help people make global linkages with local patterns. There was, however, little mention of particular transportation routes or other local specifics of the transportation system.

### *Land Use*

Land use was represented in both tools, although it was significantly more central in terms of data in the atlas than the footprint (Table 1). Land use in the atlas was represented by six layers, including two for green space. In the footprint, land use was implicit in all layers but was directly represented by only the built land component. Participants in all groups incorporated green space and land use in their unprompted introductory conversations in the first period. During the actual use of the tools, atlas groups discussed land use in detail. Footprint groups rarely mentioned it.

*Atlas* Discussions of land use in the atlas focus groups were stimulated via the manipulation of several land use, forest cover, and transportation data layers. Participants focused on increased development in specific areas and expressed concerns about green space. These comments on viewing current green space and forest layers are fairly typical:

*Berthe:* That's it? That's all we have left?
*Moderator:* Yes.
*Berthe:* Oh my god. It used to be all green here you know. All green because we used to go for walks and walks and walks.

Participants often used local landmarks, such as particular stores or roads, to discuss specific

developments. One woman pointed to a portion of the screen and explained that when "we used to come with our kids this was nothing, this was not developed. [The borough of] Pierrefonds didn't have anything." Similarly, the rapid increase in condominium development was a concern.

*Bev:* There is a huge amount of condos being built, like five or six of them at once that are just being . . .
*Jen:* I live just down the street from them.
*Sylvie:* Yeah.
*Bev:* And they are just, they are just throwing up condos left right and center and you know they are not thinking about, they are not thinking about how that is going to affect the rest of us. Like how, you know?

The apprehension about development underscored a sense of lost control over community. A participant in another group summarized this as, "it's [development] all over the place, they are really invading our place." This perspective characterized development as a spatially bounded local phenomenon that happened to community residents but was not caused by them. Proposed actions were similarly local and centered on preserving green space in the form of neighborhood parks or local tree cover.

Discussions about land use were intense and participants contributed additional information from personal experience to the data presented. Conversations were fixed to the local scale and contained little integration of land use impacts across scale. The problems of land use were seen to be almost wholly external—local developers and deficient governmental regulation were the causes of unwelcome changes. Participants did not reflect on the social values and patterns, the drivers underlying the change, but did provide rich considerations of locally specific developments and places.

*Footprint* In comparison, the subject of land use was minimally discussed in footprint groups. When the built land variable was displayed, two groups held brief conversations about green space. In one case the link between trees as carbon sinks and a local policy of subsidized tree planting was made. In another group built land was used to justify activism to protect green space. This group made linkages between culture and the value placed on green space. As one participant put it, devaluing nature, and cutting trees in particular, "is in our culture, we come from the first settlers, the voyageurs who were fur-traders and for us nature was overabundant and there was so much of it and we've got it engrained in us. That is an explanation that could be questioned but it's the reality of the situation, the critical situation."

Participants in all eight focus groups expressed strong concerns for the preservation of green space. For participants in footprint focus groups, the majority of these discussions occurred either during the unstructured introduction period before tool use or after the tool use in the third period. This would indicate that the use of the footprint inhibited discussion of specific local, spatial concerns such as green space and land use. When greenspace was discussed in conjunction with the tool, it was linked to broader social patterns and to the abstract notion of the environmental benefit of trees.

### *Waste Management*

Waste management was not included in the atlas as no land in the West Island is used for waste disposal, and it was not discussed spontaneously by any of the atlas groups. As an issue included in the flip chart, however, all groups were asked to consider it. Waste was a major factor in the footprint and the data presented eight differentiated categories of waste, including recycling and commercial wastes.

*Atlas* Participants in two atlas groups considered waste management during the introductory period but no group discussed it during the use of the tool. All atlas focus groups discussed waste at least perfunctorily because it was an item on the flip chart. One prominent waste theme was littering. Three groups responded by recommending education to prevent this behavior. Composting was mentioned in two groups; to increase local involvement, composting had to be made more convenient.

*Bev:* and the whole leaf thing . . .
*Sylvie:* Well in—you used to be able to buy paper bags and you'd put your leaves

and they would pick it up and compost it. I don't know if they still do that. The thing is that with those bags you had to go to city hall and buy the bags. I mean, just drop them at my door.

*Tina:* They've got to make it more convenient.

Beyond littering, personal responsibility did not feature strongly and waste was not vocalized as a societal or behavioral issue. Instead, waste management was a local government function; redirection of materials out of the waste stream depended on its convenience. No cross-scale or cross-issue linkages emerged.

*Footprint* Waste was addressed in every footprint focus group and dominated the conversation in three groups. One group, composed of members of a community group with regular meetings, became so interested in waste management that they spontaneously decided recycling would be the subject of their next meeting.

All footprint groups framed waste as part of larger societal patterns. The following excerpt illustrates the general feeling:

*Ed:* What's the cost to recycle, and recovering? You can walk along the streets and see lots of stuff that isn't being picked up. It's just the type of society that we are—with paper cups and you know . . .

*John:* Oh yeah.

*Ann:* That's it, we're a throwaway society.

*John:* Yeah.

*Ann:* We don't even mend clothes anymore, we just throw them away.

*Ed:* Yeah.

*John:* They are not worn out.

*Ann:* Shop, shop, shop. I guess it's a lot of discretional income. When the need is there people have to make do with, but when they don't, they don't do it.

A participant in another group connected waste to the pace of life and commented that, "Everyone is so rushed and it's much more convenient to buy the prepackaged stuff with millions of wrap than to make stuff individually." Reflections about the locus of responsibility for waste management were ubiquitous. Assigning responsibility, however, proved complex. The following interaction occurred between members of one focus group who all were parents of small children. Participants were discussing solutions to unacceptably high levels of waste, especially nonrecyclables. An abrupt reversal appeared:

*Maude:* Well things that cannot be recycled, ever, should be banned. That's what I think.

*Lucie:* What about disposable diapers?

*Maude:* Disposable diapers they are, they are . . .

*Kristin:* Disposable diapers, that's a big one!!

Maude's initial assignment of responsibility to the government was challenged by Lucie's pointed question about disposable diapers. Instead of the comparatively neutral concept of governmental regulation of "bad" pollutants (and polluters), suddenly waste management became a complex moral issue. The discussion deepened as participants weighed the relative ecological harm of diapering options. People often revert to the level of the personal when discussing abstract environmental issues (Myers and Macnaghten 1998) and the footprint demonstrated the ability to allow participants to grapple with the unseen consequences of daily choices. In the shifting discourse, the individual was distantiated observer, then possible polluter, and finally potential environmental champion. All but one footprint focus group explicitly and spontaneously discussed the role of the individual in conjunction with governmental or corporate responsibility for waste reduction.

For groups using the footprint, waste management triggered considerable reflection and debate; this conversation became highly interwoven with social patterns, economic limitations and structures, governmental infrastructure, and ecological considerations. Although global impact considerations were generally not included, discourse integrated individual, corporate, and local governance scales.

## Discussion

Three findings emerge from comparison of the two tools. First, both tools supported active participation. Second, data modeling strongly impacted the scope of focus group discussions.

Third, consistent with other research (Grazi, van den Bergh, and Reitveld 2007) the scale of the data presented clearly contributed to participants' framings of the issue. All three findings hold implications for PPGIS praxis and decision support tools and for interventions promoting the three sustainability concepts: interconnection across systems, reflexivity, and integration of scales needed for sustainability.

Several implications of tool design and data representation were observed in this study. First, our results demonstrated how tools can influence discussions and shape decisions (Jankowski and Nyerges 2001a). The tools elicited considerable discussion about multiple perspectives on sustainability, including root challenges and potential solutions. Participants grasped the simplified GUI, although their interactions with the tools were relatively shallow. Both tools contained greater capacity for interaction than was utilized, which highlights the importance of chaperones to guide the participants through unfamiliar GIS processes (Haklay and Tobón 2003). Participants' willingness to accept data representation as immutable underscores the power of representation, although their ability to add qualitative content and reconstruct meaning from the data reinforces the literature (Elwood and Leitner 2003; Elwood and Ghose 2004) on the capacity of the tools to support the production of local knowledge.

Second, each tool presented some data that could not be captured in the other, which clearly shaped focus groups discussions. The atlas included several detailed layers on land use, including discrete green spaces. In contrast, the footprint represented green space only as a ratio of built land, which was represented as a continuous surface. Waste was not represented in the atlas because it is transported from the area; whereas, it was represented by several data "slices" in the footprint. It is not accidental that the major topics of conversation for atlas groups included land use, whereas waste management was central for footprint groups. Transportation elicited conversations in both sets of groups but the discourse differed significantly. Atlas groups employed the line features of transportation to focus on safety, congestion, and access; footprint groups used the choropleth to debate global ecological damage and values attached to automobile dependency.

A third and related point is that the scale of data mattered in tool use and interpretation of data. The atlas showed high variability across the spatial extent and contained data at a high resolution—for example, individual parks and nonarterial roads—that could be viewed and zoomed in and out. Spatial relations and their associated attributes could be explored. The footprint contained data at low resolution and variability. Footprints were generalized to boroughs and included no specific neighborhood features. The footprint likely cannot support specific land use or infrastructure decisions and obscures intracommunity variation. For example, features that highlight conspicuous consumption or poverty (e.g., a brownfield or residences among a concentration of heavy industry) are lost or inferential. Indeed, the larger spatial variation in the atlas created the impression that it held more information than the footprint, even though the atlas contained five fewer layers. The detail allowed the atlas to support deeper locally specific conversations, whereas conversations in the footprint focus groups rapidly jumped to contemplations of broad societal patterns.[2] This trade-off—detail stimulating local discussion but distracting from contextual assessments—highlights the importance of anticipating the relationship between the tools and their likely discourse before using them.

The footprint mitigated the fixedness of scale and enabled participants to transcend the local to reflect on the socio-political and economic production of geographic scale at which consumption and sustainability occurs. It clearly supported integration of scales as well as interconnection across systems and reflexivity in terms of social values and norms. In the atlas, the spatially detailed representation of landmarks, transportation corridors, and specific parks supported connections between systems at the personal level but fell short in supporting integration across scales or reflexivity about values. For example, atlas groups discussed personal experiences of the interconnection between transportation infrastructure and other aspects of their lives—such as safety, social mobility, and access to social and economic resources—but failed to consider global ecological impacts or to reflect about connections among transportation, social structures, and underlying values. Similarly, although land

use was a major concern, these groups emphasized negative impacts of residential development without questioning values or societal patterns. The atlas groups characterized waste management as a local aesthetic issue—littering—rather than a sustainability issue.

Conversely, the footprint downplayed the West Island's spatial distributions and participants paid attention to the abstract impacts of the decisions made in the boroughs. All four footprint groups focused on the social values and norms underlying our current system and drew connections between local and global aspects of sustainability. Participants in footprint groups discussed the multifaceted nature of responsibility at the level of individuals; local, regional, and national governments; and societies. This multiscalar emphasis allowed participants to connect specific and local problems to broader patterns and actions and suggests that although the footprint does inherently involve a hierarchical understanding of scale, it does not enforce a strict binary between agency and structure in which individuals' powers to shape the global are excluded. Instead, it allowed the messiness of responsibility and agency across multiple scales to be discussed reflexively by participants. To some extent the footprint also demonstrated an ability to support discussions of the connections between systems. Footprint group participants routinely made connections among social, economic, and ecologic systems. However, participants had little discussion of personal use of community space or local specifics and groups volunteered less information about their communities than was done in the atlas groups. The EFA supported reflexive consideration of links across systems and across scales but at the expense of local particular detail. The atlas appeared to promote insightful discourse on the local, but conversations tended not to go beyond that.

The two tools resulted in different conversations but similarities emerged across groups. Substantively different groups, for example, the urban poor or ethnic minorities with other priorities or groups with less computer experience, might not have responded in kind. This study contains some bias by class, race, and suburban location. Nonetheless, findings hold valuable implications for areas of the highest ecological footprint, suburbs, where disproportionate amounts of land are being converted due to low-density use and where levels of domestic consumption are high.

## Conclusions

This research developed two GIS-based tools for sustainability and evaluated their performance in terms of PPGIS and by three criteria related to sustainability. Both tools engaged focus groups in lively conversations about community issues but differences did appear. The footprint enables more abstract, less locally grounded issues to emerge and supports comparatively deep reflections on social behavior and responsibility. At the same time, however, it had difficulties fully representing a local scale and did not elicit information from community members. Just as the atlas cannot support the level of abstract consideration engendered by the footprint, the footprint was unable to support the level of specific, spatially defined, detailed discussions of the atlas.

Information can both enable and constrain. Both the atlas and the footprint tools have strengths, but each also limits consideration of certain aspects of sustainability. The strength of EFA is its ability to foster consideration of personal and social responsibility, but the atlas focuses more clearly on specific local government decisions. It is possible that an ideal situation might be the combination of the two tools, so that personal, societal, and governmental responsibilities can be more fully incorporated in local sustainability planning that does not ignore the global scale. The footprint can promote thinking globally; the atlas can promote acting locally. A public participation process could start with locally grounded discussions using an environmental atlas and then move into the broader debates triggered through the visualizations of the ecological footprint. The overarching message is that the right tool will depend on the specific needs of the community and the stage of the decision process. It is equally important to realize, however, that the results of a process of public engagement in sustainability issues might, in fact, reflect the choice of tool and data presentation rather than real public concerns.

That two PPGIS tools with a common purpose can produce two such differing outcomes

makes two important points: one that data representation does influence the nature and outcome of public participation; the other that in using PPGIS tools to support sustainability dialogue, users must be conscious of and explicit about the data representation and tools used to reach any given conclusion arising from public participation. Failure to understand this can lead to significant incidental errors; worse, success in understanding this can lead to deliberate manipulation.

Future research could integrate formal decision support approaches into the tools, for example, to weight alternate solutions to improving sustainability. Tools should be embedded within broader policymaking constructs, such as participants' expectations of their involvement in any decision-making processes, group behavior, and institutional influence on the process (Jankowski and Nyerges 2001a). Strong sustainability initiatives will need to link engagement to action. ■



## Notes

[1] Although this is the only work we know of that has attempted to combine EFA with GIS in this way, there are extensive resources for creating EFAs in general. A companion paper(Klinsky, Sieber, and Meredith 2009) outlines the method used in this study in depth. Other key resources include Wackernagel and Rees (1996), Chambers, Simmons, and Wackernagel (2000), and the Global Ecological Footprint Network (http://www.footprintnetwork.org).

[2] Differences also arose from technological constraints; for example, the inability of ArcScene to mark grids that would distinguish marginal contributions of thin components such as food consumption.

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