Reimagining Technology: Anthropology, Geographic Information Systems, and the integration of diverse knowledges

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Abstract

The integration of scientific and local or indigenous knowledges has become a central issue for the management and development of natural resources This paper problematises the integration of scientific and local and indigenous knowledges through an analysis of the use of Geographic Information Systems (GIS) by natural and social science researchers. In particular, the explicit claim for GIS as a technology to facilitate the integration of diverse knowledges will be examined. However, rather than pursue a more conventional focus on participatory GIS research methodologies, this article develops a theoretical framework to investigate the ontological boundaries and epistemological privilege implicit in the use of GIS that may actually undermine the claim for GIS as an integration domain. Latour's concept of 'a symmetrical anthropology', developed in conjunction with notions of 'knowledge making', is applied to three case studies illustrative of the use of GIS as an integration domain. It is argued that a symmetrical anthropology is a particularly useful theoretical approach that not only reveals the implicit assumptions that undermine the use of GIS as an integration domain, but also provides a vantage from which to explain GIS technology as a network of social and technical interactions. In conjunction with other research concerned with interactions between diverse knowledges and digital technologies, such an approach paves the way for re-imagining GIS as an integration domain.

Since the 1990s there has been increasing awareness of the relevance of indigenous and local knowledges to the management and development of natural resources (Agrawal 1995: 413-414; Nader 1996:7). This has led to an escalation in the number and intensity of interactions between scientists and local and indigenous peoples, and attempts to integrate local or indigenous knowledges into the predominantly scientific realm of natural resource management. Both natural and social science researchers increasingly rely on Geographic Information Systems (GIS) to integrate diverse knowledge, prompting an explicit claim for GIS as an integration domain (Aswani and Lauer 2006:81; Payton et al. 2003:355). Significantly, this claim is reinforced through the volume of environmental research work that prioritises GIS as a research and decision-making tool (e.g. Robiglio 2003; McCall and Minang 2005; Newman and LeDrew 2005), and the actual design of the technology itself that aligns strongly with scientific knowledge and yet simultaneously prioritises the merging of disparate information sources.

GIS are database management systems that focus on spatial analysis and the cartographic display of spatially referenced information[1]. Datasets take the form of separate layers that relate to specific natural or cultural variables that describe the environment of interest in a particular research project (Campbell 2002:190). The correlation between datasets can be analysed, and multiple datasets can be overlayed to produce a visual representation or thematic map covering various issues. Significantly, GIS manage large amounts of information and provide the tools to merge information from different sources. Thus, satellite data, aerial photography, and spatially referenced data on, for example, demographics, land and sea ownership, land and sea resource use, infrastructure, government divisional boundaries, sacred sites, vegetation, land forms, archaeological findings and so on can be overlayed and analysed to reveal various and often previously unacknowledged socio-spatial relationship patterns. Indeed, according to Dorling and Fairbairn, "GIS can be viewed as a new technology [that] makes visible a previously unseen perspective, opening up new worlds to our eyes" (1997:123). Consequently,

[1] In contrast to knowledge (social, contextual, performative, located), information is variably defined as 'about facts', 'devoid of meaning', anything that can be digitised, and data that serves some purpose (Pickles 1999:51, Longley et al 2005:12). In the early 1990s, critics of GIS within the discipline of geography highlighted the retreat from knowledge to information ensconced within GIS use (Taylor 1990, Taylor and Overton 1991).

researchers and decision makers from many diverse disciplines increasingly rely on GIS to manage and resolve environmental problems, governance issues, health crises, business questions, sustainable development, natural disaster responses, and public safety situations.[2]

As GIS is a powerful technology with potentially 'world-making' consequences, the claim for GIS as an 'integration domain' necessitates a critical analysis of the processes and assumptions embedded within such research. The approach generally taken by researchers who recognise the relevance of local or indigenous knowledge is to focus on participatory research methods that assume 'by participating in the research process, [indigenous] people are in control of their contribution' (Williams 2005:27). Whilst there is an intention to maximise the participation of local and indigenous peoples, this approach fails to problematise GIS as a technology of integration. Rather than focus on the participatory aspect of GIS methodology, about which there is an abundance of literature (Gambold 2001, Robiglio et al 2003, Chapin et al 2005, McCall and Minang 2005), this article draws attention to ontological boundaries and epistemological differences often implicit in research that seriously compromises the potential for GIS as an 'integration domain'.

Symmetrical Anthropology

The nature-culture dichotomy constructs ontological boundaries that are deeply embedded within modernist epistemologies (Descola and Palsson 1996:12). Latour (1993:99), in his critique of modernity, identifies the dichotomy as the 'First Great Divide' – the one that defines 'Us' as modern, and that also accounts for the 'Second Great Divide' between 'Us' and 'Them'. He argues that the absolute differentiation between 'western' cultures and all other cultures results from the 'exportation' of the internal nature-culture divide that is fundamental to 'western' thought and being. According to Latour, this is played out in the 'West' through a belief that 'we [westerners] do not mobilize an image or a symbolic representation of Nature, the way the other societies do, but Nature as it is, or at least as it is known to the sciences – which remain in the background, unstudied, unstudiable, miraculously conflated with Nature itself' (1993:97).

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2 Many examples of GIS use can be found in Sappington 2003 and Campagna 2006.

However, Latour proposes that the divide between nature and culture, rather than defining reality, defines the 'particular way Westerners had of establishing their relations with others as long as they felt modern' (1993:103 [my emphasis]). In order to sustain this sense of being 'truly modern' the practices of 'translation' that create hybrids of nature and culture must be kept separate from the practices of 'purification' that create the distinct ontological realms of 'human' and 'non-human', 'culture' and 'nature' (Latour 1993: 10-11). Latour (1993: 41) argues that whilst 'moderns' simultaneously bracket off and ignore the practices of translation, and credit only the practices of purification for their success, it is the link between these two sets of practices that has allowed 'us' to be modern.

The hybrids identified by Latour link 'imbroglios' of sciences, technologies, strategies, politics, economics, anxieties, fiction and so on, such that the AIDS virus and aerosols (Latour 1993: 2), the Gulf Stream (Latour 1998: 209), a door closer (Latour 1988), land titles (Verran1998: 250), and the human modified cell (Strathern 1996: 525) are all hybrid objects that trace 'delicate' networks of humans and non-humans[3]. However these networks remain invisible, severed into segments where there is only science (objects of external reality) and only sociality (subjects of society) (Latour 1993:4, 95). Latour (1993:41-42) argues that by not thinking about the connections between nature and culture and thus the consequences of hybrids for the social order, 'moderns' have been able to innovate in the mass production of multiple combinations of humans and non-humans. He contrasts this with 'premoderns' whose incessant preoccupation with the connections between nature and culture works to limit the expansion of these connections because every hybrid becomes 'visible and thinkable' and a dilemma for the social order.

Whilst the terms 'modern' and 'premodern' are problematic, Latour pursues his argument to where the relations between 'us' and 'them' are transformed and a comparative anthropology becomes possible. To focus attention on the networks of humans and non-humans that proliferate beneath the 'Great Divides', that is to apply symmetry, reveals that nature and culture are not distinguished, and that 'we have never been modern' (1993:11,

[3] Haraway (1991: 150) suggests we are all hybrid objects, 'cyborgs' that signal a breach of the supposed boundaries between humans and non-humans. She argues that cyborg imagery can express a responsibility for the social relations of science and technology, and 'suggest a way out of the maze of dualism in which we have explained our bodies and our tools to ourselves' (1991: 181).

103). As Latour suggests, 'Cultures – different or universal – do not exist, any more than Nature does. There are only natures-cultures, and these offer the only possible basis for comparison' (1993:104). The principle of symmetry requires that both 'objective truth' and 'subjective belief' are treated equally, traced as natures-cultures rather than understood through the 'Great Divides' that assume a distinction between or overlap of nature and society. As a result, an anthropologist 'in the field' could no longer rely on a universal 'nature' upon which to interpret mere 'cultural representations', and 'symmetrically' an anthropologist of scientists 'at home' could no longer simply reveal the subjectivity of scientific claims to Nature (1993:101-102). Instead, 'culture' and 'nature' must always be problematised, leaving only natures-cultures for comparison (1993: 101).

It is important to recognise that, as Pickering highlights, 'the foundations of modern thought are at stake here' (1992:22). As Descola and Palsson (1996:2) state, the nature-culture dichotomy has provided analytical tools that have been central to the discipline of anthropology since the 1950s. Whilst developed and applied differently by materialists, cultural ecologists, structuralists, and symbolic anthropologists, what was actually understood as 'nature' and 'culture' 'always referred implicitly to the ontological domains covered by these notions in western culture' (Descola and Palsson 1996:3). The dichotomy was taken for granted, and as such, left unexamined. However, despite its 'taken-for-grantedness', which continues to permeate 'western' commonsense understandings and scientific practice (Descola 1996:88), the epistemological implications of a nature-culture dichotomy are now being addressed within the discipline of anthropology. As a result, anthropologists and other social theorists have revealed that the nature-culture dichotomy fails to adequately explain the ways people talk about and interact with their environments (Cruikshank 2001; Hviding 1996; Povinelli 1995), and indeed 'hinders true ecological understanding' (Descola and Palsson 1996:3).

A number of anthropologists working within Australia have pointed out that, contrary to western epistemology, many different Aboriginal peoples attribute subjective intentionality not only to humans, but also to animals, land, objects and Dreamings, and that this constitutes very different human-environment relations (Bradley 2001:298; Meyers 1986; Povinelli 1995; Rose 1992:90-91; Strang 2000:282-283 and 2005:369-370). In her paper, Do Rocks Listen, Povinelli (1995) relays the description by a Belyuen woman, made to the land commissioner during the Kenbi Land Claim, of how Old Man Rock 'listened to and smelled the sweat of Aboriginal people as they passed by hunting, gathering, camping, or just mucking about' (1995:505). Povinelli then draws attention to a related comment offered by another Belyuen woman about the land commissioner - 'He can't believe, eh Beth?' (1995:505).

Povinelli (1995:505) reveals that 'matters of belief' plague the interactions that Belyuen people have with anthropologists, ecologists, environmentalists, legal people, and tourists. In these situations, the human-environment interactions described by Belyuen women are positioned within a Western framework that distinguishes between 'nature' and 'culture' and that subsequently upholds 'commonsense' notions of human action in the natural world (1995:507). Within this framework, Belyuen understandings of human-environment interactions are, according to Povinelli, problematically 'represented as beliefs rather than a method for ascertaining truth' (1995:506). This is an example of Descola's point that boundaries that define 'human' and 'non-human' relations that are different from western epistemological and ontological boundaries appear as 'intellectually interesting but false representations, mere symbolic manipulations of that specific and circumscribed field of phenomena that we call nature' (Descola 1996:88). Povinelli argues that this reflects the 'deep disbelief' within western epistemologies that non-human entities can be intentional subjects, and contributes to the problem of how to integrate or represent local non-western knowledge of the environment (1995:506).

Likewise, Cruikshank (2001) discusses the sentient glacial landscapes in the narratives of the indigenous people in north-western North America and the problems associated with incorporating these understandings into global debates on climate change. As she suggests, 'glaciers that are equipped with senses of smell and hearing, alert to the behaviour of humans and quick to respond to human indiscretion, sound wholly unlike glacier field sites where scientists can 'sieve' for reductive moments that allow measurement of variables involved in climate change' (2001:389). In relation to the incorporation of indigenous understandings into global debates, Cruikshank (2001:389) points out that local knowledge is often problematically reified as 'traditional ecological knowledge' (TEK). In order to incorporate TEK into various natural resource management plans, diverse indigenous knowledges are made bridgeable through a scientific framework of 'biodiversity', 'sustainability', and 'co-management'. As a result, the sentient landscapes of the indigenous people in north-western

North America are transformed into 'land and resources' that are devoid of social content (2001:389).

Hviding (1996:168) argues that the study of indigenous ecological knowledge often produces information on local taxonomic representations of 'nature' rather than understandings of the interactions and relations between people and their environments. This is supported by Scoones' (1999) review of ecological thinking in the social sciences. Scoones suggests that whilst there is a vast literature on indigenous ecological knowledge, 'the consequence has been the collection of much data – classically in the form of lists and classifications – that remain poorly situated in the complexities of environmental and social processes' (1999:485). Therefore the conventional study of indigenous ecological knowledge establishes a platform that can potentially be used to test the 'validity' of indigenous knowledge against the objective 'reality' of scientific knowledge (see Hviding 1996:169). Indeed, Watson-Verran and Turnbull reveal that 'by and large, past cross-cultural work has taken Western 'rationality' and 'scientificity' as the bench mark criteria by which other culture's knowledges should be evaluated' (1994:115). As a result, the privileged access to 'nature' afforded by scientific knowledge has reinforced notions of 'rationality' and 'objectivity' that, linked with non-indigenous systems of power and authority, has constructed a divide between scientific and indigenous knowledges.

However, the divide between indigenous knowledge and scientific knowledge is being dismantled through a critical examination of the concept of 'indigenous knowledge' (Agrawal 1995) and the revelation of science as a social activity (Turnbull 1997:553; see also Latour 1998). The concept of indigenous knowledge and its distinction from scientific knowledge has long been associated with the field of development studies and the discipline of anthropology, and more recently with environmental conservation (Agrawal 2002). Indeed, whilst 'indigenous knowledge' has been transformed from something 'inefficient, inferior, and an obstacle to development' in the 1950s into something that held value for sustainable development and natural resource management issues in the 1990s, the distinction between indigenous knowledge and scientific knowledge has generally remained fundamental to the understanding of 'indigenous knowledge' (Agrawal 1995:413). This is an important distinction because an increased awareness of the relevance of indigenous knowledge has not only revealed a space of intersection between indigenous knowledge and scientific knowledge, but has also flavoured that space with notions of opposition.

Agrawal (1995) offers a critique of the divide between indigenous and scientific knowledge through an analysis of what he defines as the major themes of division (1995:418). These themes establish indigenous knowledge as intimately engaged with the activities associated with the everyday lives of people rather than being concerned with abstract ideas and philosophies; as closed, non-systematic and devoid of notions of objectivity or rigorous analysis; and as contextually bound by a particular people living in a particular place. In contrast, scientific knowledge is identified as separate from everyday livelihoods, as abstract, analytical, objective, and universal (Agrawal 1995:422-425). Agrawal argues for a multiplicity of knowledges to challenge this dichotomy between indigenous and scientific knowledge (1995:433). He presents evidence for both the context of science and the abstraction of indigenous knowledge, and suggests that 'the same knowledge can be classified one way or the other depending on the interests it serves, the purposes for which it is harnessed, or the manner in which it is generated' (1995:433). Attending to both the sameness and the difference of 'knowledges', as revealed by Agrawal, establishes a basis from which to bridge the constructed chasm between indigenous and scientific knowledge (1995:433).

Knowledge assemblages

In order to consider this 'bridge' it is necessary to examine notions of sameness and difference as they relate to the assemblage of knowledge. Turnbull questions the view of 'science as specially privileged knowledge', and instead recognises science as a local knowledge system assembled through a set of local practices (1997:553). He argues that all knowledge is both performative and representational, and that knowledge is assembled in particular ways to produce a 'knowledge space' made up of people, skills, local knowledge and equipment (1997:553, 560). Various social strategies and technical devices enable the components of knowledge spaces to be connected. Turnbull (1997:553) argues:

> because all knowledge systems from no matter what culture or period, have localness in common, many of the small but significant differences between knowledge systems can be explained in terms of the differing kinds of work involved in creating 'assemblages' from the 'motley' collection of practices, instrumentation, theories and people.

Turnbull (2000) examines specific 'knowledge assemblages' of different groups of people: premodern European masons, cartographers, Polynesian navigators, medical research scientists, and aerospace engineers. The various social strategies and technical devices for the movement and assemblage of knowledge are examined, and in all cases he demonstrates that 'knowledge is necessarily a social product; it is the messy, contingent, and situated outcome of group activity' (2000:215). Turnbull's approach to 'knowledge' reveals both the 'situated messiness' of scientific practice and the collective work involved in assembling scientific knowledge from otherwise heterogeneous knowledges. His examination of particular scientific research projects in the fields of malariology and turbulence engineering show that scientific knowledge is produced 'at specific organised sites by people in face-to-face circumstances and results from contingent chains of negotiated judgements and concrete practices' (Turnbull 2000:184). Turnbull reveals that whilst scientific practice and results can be messy and controversial, and intimately local and discrete, still an assemblage can be achieved that moves knowledge beyond the local.

Turnbull's analysis of knowledge as both practice and collective work not only challenges understandings of science as (true) representational knowledge, but also recognises the mobility of local indigenous knowledge. Such recognition challenges assumptions that indigenous knowledge is somehow bound or limited by locality and subsistence anxiety, and subsequently is unable to transcend the here and now. In particular, Turnbull focuses on the knowledge of Polynesian navigators that is assembled through various social strategies and technical devices that enable deliberate journeys across a vast ocean (Turnbull 2000:153). Of importance here is Turnbull's insistence that oral traditions (generally associated with local indigenous knowledge) engage processes to assemble and move knowledge beyond its local production.

The fundamental role of narratives to structure and transmit knowledge associated with all aspects of Australian Aboriginal life is well documented in the literature (Klapproth 2004; Meyers 1986; Rose 1992; Strang 2000; Watson 1993). Watson (1993:28) considers the 'knowledge network' of Yolngu people of northeast Arnhemland. She argues that 'Yolngu knowledge is coincident with the creative activity of the Ancestral Beings', and that subsequently, 'knowledge and landscape structure and constitute each other' (1993:30). As the 'whole country' is constituted by an already established network of tracks made by the ancestors, the specific knowledge held by specific people and clans about specific country resides in the landscape and transcends the 'local' through its 'place' in the network.

In the context of Aboriginal claims to land, Strang (2000) explores the transcendental landscape of Aboriginal people in Kowanyama in North Queensland, and in particular its relationship with other technologies and strategies of knowledge mobilisation. Whilst travelling through their country, local knowledge from each place is recorded in 'Western' artefacts (e.g. maps, databases, film) for the political and social gain of Kunjen people in the land claim process (Strang 2000:289). The complex of land-people-knowledge is represented through the 'showing and telling' of each place, a performative strategy used by people in Kowanyama to establish their knowledge and ownership in various interactions with scientists, tourists, anthropologists, government officials, and so on (Strang 2000:280, 289). Concurrently, 'alien representational forms' such as maps, databases, and other technical devices are used to record their knowledge in order to assert an Aboriginal reality within a contentious political arena (Strang 2000:278-279). It is important that Strang's focus on the agency of Kunjen people in land claim processes reveals the particular social strategies and technical devices engaged by them to 'move' their local knowledge into a broader political and legal debate on land ownership.

Indigenous knowledge, conventional databases, and digital technologies

Whilst in agreement with Strang that many Aboriginal people in northern Australia are using digital technologies to promote their own interests, Christie (2005a, 2005b) explores the compatibility between the conventional production of databases as a repository of objective knowledge (as in the production of a GIS database) and Aboriginal knowledge production[4]. Christie (2005a:6) recognises that significant aspects of Aboriginal knowledge are lost through the process of abstraction which removes the particularities and localities of knowledge production in order to record within a database the 'factual' knowledge. Christie's (2005a: 10, 12) analysis of the use of digital technologies by Yolngu people highlights the tension between scientific and Aboriginal metaphysics, and contributes to the realisation that rather than

4 See Bartolo and Hill (2001) as an example of the conventional use of GIS databases within northern Australia.

being neutral objects, conventional databases prioritise a Western objectivist ontology. That is, within a conventional database, the sequestration of metadata into predetermined fields enforces a priori ontological relationalities that reflect a scientific metaphysics and stifle the power of Aboriginal knowledge production (2005b:56).

Rather than accept the necessity of metadata fields, Christie (2005b:60) works with a recognised connection between Aboriginal and computer ontologies to pursue an 'ontologically flat and epistemologically innocent database' (see also Glowczewski 2005). Through problematising the processes of use and design of digital technologies (distinct processes in Western knowledge practices), Christie attends to the multiple connections of and between people, knowledge, place, and technology, and in so doing invokes Turnbull's 'knowledge assemblages' and Latour's 'natures-cultures'. The challenge of a symmetrical anthropology is to pursue a similar tracing of these connections 'at home', in a state where culture and technoscience are deemed never to overlap.

Integrating soil knowledges in East Africa and Bangladesh

Payton et al (2003:357), in a paper based on East Africa and Bangladesh, support the widely accepted view that sustainable land management is most effectively derived from the synergy of local and scientific knowledge, and argue that more attention needs to be given to integration methodologies (see also Sillitoe 1998a; WinklerPrins 1999:156). The authors investigate two research projects that apply different methodologies for the integration of scientific and local knowledge of soil and land resources within GIS. The research projects were based in the lake region on the border between Tanzania and Uganda in East Africa and on the floodplain regions in Bangladesh. Both of the research projects involved interdisciplinary teams of natural scientists, anthropologists and other social scientists, the participation of local farmers, the collection of scientific and local knowledge about soils, and the use of GIS as an 'integration domain' for scientific and local knowledge (2003:358). Both projects also employed conventional scientific soil survey methods that involved transect surveys, geo-referenced representative soil samplings, laboratory analysis, and the recording of soil properties and site details according to internationally accepted methods (2003:361).

Despite these shared themes, the projects differed in their methodology in terms of the 'collection' and assessment of local knowledge and the integration of local and scientific knowledge within a GIS (Payton et al 2003:358). In the East Africa project, local knowledge research focussed on the production of a geographically accurate local knowledge soil map and the development of a meaningful local knowledge map legend. Field methods included participatory mapping, semi-structured interviews, farmer-led transect walks, household interviews, key informant interviews, and focus group discussions. Participatory mapping began with farmers drawing cognitive maps of local soil types, and following group discussion of soil categories and boundaries; a local knowledge soil map was produced. In order to achieve the 'geographical accuracy' suitable for GIS work, the farmers were then asked to transfer this information onto aerial photographs (2003:363-364). The overall study involved interviews with individual farmers in their fields in order to explore 'criteria for soil and land classification in more depth' and to geo-reference soil boundaries using a global positioning system (GPS) (Payton et al 2003:364). Focus group discussions were used to cross-check the information from individual farmer interviews and to produce a final 'consensus' local knowledge soil map. According to Payton et al, the 'focus group discussions were useful for further refining and contextualising the information and were used to develop consensus [local knowledge] map legends' (2003:364).

In the Bangladesh project, local knowledge research was not specific for soils, and instead focussed on 'all aspects of natural resource management' (Payton et al 2003:365). The project relied on ethnographic research carried out by two anthropologists resident in the field for 18 months. Research methods included open-ended discussions, some participant observation, and plot-by-plot interviews with land-owners in 600 rice paddies (2003:365). Local soil names were included in the GIS by plot location rather than by GPS, made possible through the use of a detailed base map that showed individual rice paddies (2003:361).

The integration of local and scientific knowledge within the GIS was also approached differently by each project. This difference related specifically to the integration of local soil knowledge rather than to the entry of data from the scientific soil surveys (Payton et al 2003:365). In the East Africa project, the various farmer drawn maps, supported by the 'consensus' local knowledge map legend, and the geo-referenced interview data were entered into the GIS (2003:365-366). Integration analysis involved the use of scientific and local knowledge map overlays to examine the degree of correspondence between scientific and local knowledge soil maps (2003:366-367). In the Bangladesh project, geo-referenced local knowledge of soil classification and soil boundaries were entered into the GIS. However, in an attempt to avoid the extensive 'filtering' of local knowledge prior to the integration with scientific knowledge, a computer-assisted qualitative data analysis software (CAQDAS) package was used to store, sort and code interview transcripts (Payton et al. 2003:367). Whilst this process made local knowledge accessible to soil scientists, much of the ethnographic research was not extensively geo-referenced and subsequently it was difficult to integrate local knowledge with the scientific soil maps in the GIS (2003:380). In their critical assessment of the use of GIS as an 'integration domain', Payton et al reflect on a number of issues. Firstly, as the assessment of 'soil spatial variability' was a fundamental aspect of the scientific soil research (2003:357), the authors had to contend with 'the issue of defining boundaries that result from the variable density and elastic scales of farmer's personally constructed [local knowledge]' (2003:380). They recognise that the spatial cognition of farmers is not equivalent to the scientific representation of space, and acknowledge that 'asking farmers to create a cartographically faithful cognitive map from memory is flawed' (2003:380). Whilst Payton et al suggest that this problem is somewhat overcome through the use of GPS in the East Africa project and through the use of cadastral maps in the Bangladesh project, the translation of local knowledge soil boundaries onto maps remains problematic for spatial analysis (2003:383).

Secondly, the development of a 'consensus local view' was identified as an important process in the use of GIS as an integration domain. The authors note that whilst Bangladeshi farmers name soils according to the soils' feel, and that these names relate closely to scientific concepts of soil texture and consistency, 'unlike the scientific approach, they are not consistently applied using objective and repeatable criteria to all soils by all farmers' (Payton et al 2003:378). Likewise, the East African project showed that whilst farmers use criteria to classify soils that 'parallel' scientific soil classification, 'these criteria are not assessed or applied systematically or quantitatively as in scientific approaches … and they vary in their application between individual farmers' (2003:376). Subsequently, Payton et al argue that, as local soil knowledge is experientially based and farmers have a better knowledge of the soil that they farm, the integration of local knowledge into a GIS requires the aggregation of farmers' knowledge (2003:380, 382). However they also recognise that 'the distillation of [local knowledge] to provide tabular information for the GIS involved in this process inevitably results in loss of detail and context' (2003:383).

Finally, Payton et al highlight the importance of 'context' in relation to farmers' local knowledge of soils (2003:383), and the need to facilitate the comparison of local and scientific knowledge conceptually as well as spatially (2003:379), stressing that 'It is crucial to recognize that farmer's knowledge is not neutral or static but is developed through communication, interpretation and action and is sensitive to particular contexts' (2003:377). The authors suggest that an ethnographic approach is necessary to ensure that the context of local knowledge is 'properly appreciated', and that the use of GIS in conjunction with CAQDAS could 'provide an integrated analysis that is socially contextualised and yet detailed and spatially reliable' (2003:383). In terms of an integrative methodology, the authors advocate initial intradisciplinary studies focussed on either local knowledge or scientific knowledge, followed by a process of knowledge sharing, and proceeding to in-depth studies based on the need for iteration between the two knowledge systems. They conclude that 'more substantial synergy can then be achieved through the joint interrogation of interdisciplinary databases' (2003:383).

Designing Marine Protected Areas in the Solomon Islands

Aswani and Lauer (2006a, 2006b) incorporate scientific knowledge and local ecological knowledge and behaviour into a GIS for the design of marine protected areas in the Roviana and Vonavona Lagoons, Solomon Islands. Their research projects involved a combination of spatial tools, anthropological fieldwork, and social and natural science methods to study artisanal fisheries (2006a: 83) and benthic knowledge (2006b:263). The research reported in these papers, along with social assessments and an understanding of customary marine tenure systems contributed to the final selection of marine protected area locations of ecological and social significance (2006a:85, 2006b:264).

Aswani and Lauer (2006a) outline biological objectives to 'protect vulnerable species and habitats' and social objectives to encompass local practices to 'enhance community well-being throughout the region' (2006a:84-85). Subsequently, in order to identify vulnerable habitats and susceptible species, local ecological knowledge of habitats and biological events were coupled with scientific knowledge within the GIS, along with spatial and temporal patterns of various human fishing activities. In their paper focussing on knowledge of the marine benthos, Aswani and Lauer (2006b) support the accepted view within resource management literature that benthic mapping is the 'crucial first step' in characterising the marine environment for the design of protected areas (2006b:263). Through their work they recognise that local ecological knowledge of habitat classification distinguishes between abiotic benthic substrates, biotic communities, and occupant species in a similar way to scientific classifications of marine habitats, and subsequently these distinctions were used in the initial phase of the mapping project (2006b:264).

The methods outlined in both papers are interrelated in terms of the overall project of establishing marine protected areas in the lagoons. Participant observation and interviews conducted over a 12 year' period were used to record local ecological knowledge. Digitised and geo-rectified aerial photographs formed the 'real-world backdrop' onto which selected 'knowledgeable' local informants drew the boundaries of habitats, abiotic and biotic substrates, and other areas. According to Aswani and Lauer, the digitised 'base map' of aerial photographs 'served as an important cartographic tool for researchers and local informants when collecting spatial data in the region' (2006a:85). In addition, researchers travelled in boats with local fishermen to map boundaries and locate biological characteristics using a GPS (2006a:85, 2006b:264-265). Local ecological knowledge was represented in the GIS by separate layers associated with locally defined bio-physical areas, fishing areas, floating sites, biological events and marine habitats (Aswani and Lauer 2006a:87). Fishing behaviour, incorporating named fishing ground, paddling times, habitat type and fish yield, was represented by linking foraging data collected during the past 12 years with more recent geo-referenced data through the shared usage of locally named fishing grounds (2006a:86). The GIS was then used to reveal spatial and temporal patterns of local fishermen's ecological knowledge and behaviour.

Conventional marine ecological surveys were employed 'for ground-truthing the accuracy of local habitat identification' (Aswani and Lauer 2006a:85), and to 'test the correspondence' between local knowledge of the benthos and the 'actual distribution of abiotic and biotic substrates in the area' (2006b:266). Aswani and Lauer report results that show a high correspondence between local ecological knowledge data and the ground-truthed field dive surveys (2006b:267). They suggest that 'such correspondence is promising, given that it corroborates an intuitive prediction that indigenous ecological knowledge as a form of inductive science is not ontologically incongruent with Western scientific knowledge' (2006a:96). Aswani and Lauer argue their results and methodology demonstrate that the participation of local people produces 'scientifically acceptable data', and that such local participation contributes to bridging the divide between local and scientific environmental knowledge (2006b:271).

Despite some conceptual limitations and a possible trade-off between scientific rigour and local participation (Aswani and Lauer 2006b:271), the authors highlight the 'great potential' of GIS as an integration domain for local and scientific knowledge (2006a:99). They argue that public participation GIS 'integrates as equivalents indigenous and Western forms of knowledge' and that the visual display capability of a GIS 'bridges the divide' between local and scientific knowledge (2006a:99). Aswani and Lauer conclude that 'the ability of a GIS to store, retrieve, analyse, and display spatial characteristics of complex systems makes it an excellent spatial analytical tool for deepening our knowledge of the socio-ecological dimensions of a system' (2006a:99).

Mapping cultural and natural resources on Cape York Peninsula, Queensland, Australia

The video, 'Call of the Country' (Guiney 1992), follows a group of anthropologists, geographers, and Aboriginal traditional owners as they map the cultural and natural resources of the Pormpuraaw community on the west coast of Cape York Peninsula (Monaghan and Taylor 1995:2-1 – 2-2). The narrator highlights the use of advanced technology in the project and that 'a union between custom and science is taking place in far North Queensland'[5]. The video begins with images of the land, local development, and the community, and establishes the mapping project as an initiative of the Pormpuraaw Community Council to assist them with future management and development decisions and to preserve traditional knowledge. An elder asserts his knowledge of the land, and laments that 'the young generation, they don't know'. Then the researchers from James Cook University arrive in Pormpuraaw with their equipment – computers, maps, personal luggage, notebooks, GPS receivers, recorders, cameras and so on. The geographers do not have time to examine all of the community area and subsequently divide the country into sample areas that

5 A similar sentiment is expressed in projects by WWF (2001) and Bartolo and Hill (2002).

serve to represent larger habitat areas. The anthropologists and geographers are seen in a room huddled around multiple maps and satellite and aerial photographs of the community area, discussing and planning their movements over the coming days. Elders are kept informed of this process. Then equipment and people are loaded into vehicles and we follow the researchers and traditional owners on a number of field visits through country.

On field visits to the sample areas the researchers document the physical features of the landscape, the vegetation and soil types, ground and canopy coverage, and Aboriginal names and usages. Traditional owners accompany the researchers and act as guides and guardians, introducing the researchers to country and providing knowledge of where to camp and where to access safe water. During his introduction to country, a traditional owner emphasises that the researchers want to look at the places and that they come with 'camera and all that and John Taylor ways', referring to the project leader, an anthropologist with a long association with the Pormpuraaw community and local cultural mapping programmes (Taylor 1984:52; Monaghan and Taylor 1995:2-1). In the field, researchers use a GPS to identify the 'exact location', voice recorders are used to document Aboriginal names and the stories, songs and histories of each place, and cameras are used to photograph 'markers' that identify Aboriginal places. Geographers carry notebooks and pens, standardised forms for recording vegetation and soil type, ribbons to mark particular vegetation, tags to identify Aboriginal names and usages of particular plant samples, and bags to take plant and soil samples back to the laboratory at the university. They 'pace' the country, counting, measuring, sampling, and recording information, feeling the soil and looking up at the canopy. Anthropologists conduct semi-structured interviews with traditional owners, asking about names and usage, stories and histories. Indeed, throughout the field visits to the sample areas, traditional owners are generally seen responding to questions and providing information to the researchers.

In contrast, the video also follows a field trip along the trail of the crocodile story. On this 'field trip' traditional owners are animated and engaged, confident and in control of the process. For many it is their first visit 'home' in many years and an opportunity to re-live the stories. The traditional owners sit on the ground around the official maps that do not reflect their local knowledge of the land. One man says 'They've muddled the map. Maps not true, it's a lie. We've got to put the map straight'. Here John Taylor responds, 'We've got to put the proper Murri names on the map'. The narrator suggests the mapping journey is an opportunity to 'revive the old ways, and at least on paper, breathe some life back into the country'. Except for the images of John Taylor sitting around a fire with his notebook and pen and researchers driving vehicles, the researchers are generally absent from this part of the video. As well as older Aboriginal men, older Aboriginal women and children are present on this 'field trip'. The everyday 'business of just living' is emphasised as an intimate part of the mapping journey, and images of eating, camping and washing are incorporated in the video, along with those of spear making and fishing, firing practices, and night-time rehearsals of the crocodile story songs. Indeed the narrator reminds us of the mapping project when he points out that these everyday living practices highlight what the land has to offer and that these will be marked on the map.

The video concludes by following the researchers back to the university where the geographers identify any unknown samples, complete the resource lists, and enter the information into a GIS. The anthropologists incorporate Aboriginal story places, songlines, sacred sites, poison places and clan boundaries to produce 'one complete map', an 'Aboriginal picture of the country'. The map is shown in the video, a multi-coloured shape that transforms itself at the touch of a computer key to reveal different aspects of the land. As a final comment, the narrator suggests that the mapping project means many things; 'the renewing of old and intimate relationships with the land, the bringing together of ancient understandings and modern methods, and the preservation of the past for the protection of the future'.

An argument for symmetry

Agricultural development in East Africa and Bangladesh, the creation of Marine Protected Areas in the Solomon Islands, and the management of natural and cultural resources on the west coast of Cape York Peninsula are all circumstances identified as benefiting from the integration of scientific and local or indigenous knowledge within a GIS. However, whilst the research projects engage with GIS as an integration domain, several aspects of the work reveal limitations in this engagement. These limitations relate specifically to the ontological divide between 'nature' and 'culture' embedded within the research and expressed variously as an emphasis on knowledge as representation, an assumed association between local or indigenous knowledge and 'belief', a forced process of generalisation, a failure to recognise science as a social activity, and the presentation of GIS technology as a neutral artefact. The research projects all focus on the classification, characteristics, and usages of such things as marine biophysical areas and habitat, soil types, and vegetation areas that are particular aspects of a supposedly already existing nature. Indeed a prominent objective of the research projects is to record local or indigenous knowledge representations of these particular aspects of the natural world and incorporate them into a GIS database. This is in accordance with Sillitoe's 'we' assumption that whilst there are obvious differences between natural scientific knowledge and indigenous knowledge, indigenous knowledge and practice still relates 'to the same world 'out there', albeit expressed in quite different idioms revealing concerns for somewhat different issues' (1998b:226). In this sense the knowledge pursued is representative knowledge; how local or indigenous people classify and use the same world 'out there' that ontologically exists for natural scientists and that is not only assumed to be universal, but is also assumed to be uniquely accessed by scientific knowledge.

Local or indigenous ecological knowledge is interpreted as a cultural grid imposed upon an objective, a priori 'nature' (Hviding 1996:168). This results in an attempt to translate local ecological knowledge, embedded as it is within social and historical contexts and practices that recognise diverse human-nonhuman relationships, into a classificatory system that mirrors that used by the natural and social scientists involved in the research. The aim is to produce 'useful' information that can be readily incorporated into a GIS. According to Taylor (1990:212), information is about facts separated from an integrated system of knowledge and recorded as an autonomous observation. It is knowledge made useful through a process of decontextualisation. Whilst both Aswani and Lauer, and Payton et al recognise that knowledge is embedded within everyday practices such as fishing and soil cultivation respectively, and in particular Aswani and Lauer place an emphasis on fishing practice within their research framework, the information deemed useful for GIS is that which is both observable and measurable. Therefore, total fish yield, species of fish harvested, and time spent at each fishing site are the types of variables incorporated into the GIS (Aswani and Lauer 2006a:87). However as Curry argues 'the reduction of the world to information … limits the ability of geographic information systems to represent the broad range of activities and elements that make up the world' (1998:56). This is particularly evident in the video 'Call of the Country' where 'John Taylor ways' of knowing and representing the landscape contrast sharply with the 'crocodile story' of the Pormpuraaw Traditional Owners. It is telling that despite this contrast in ways of knowing, the emphasis in the project remains focussed on getting Murri (local indigenous) names onto the map, classifying vegetation and recording usages (also Monaghan and Taylor 1995:2-21). Whilst stories and histories are also recorded, the entanglement of land, people and knowledge expressed and practiced by Traditional Owners in the 'crocodile story' section of the video does not translate into representative knowledge or information necessary for the GIS database. As Turnbull points out, in the Pormpuraaw mapping project 'there seems to be no recognition of the complexities of the translation process' (1999:8). The outcome is that the indigenous knowledge included in the GIS database is that which can be made to most closely model scientific ways of knowing 'nature'.

There is a similar outcome in the work by both Payton et al (2003) and Aswani and Lauer (2006a, 2006b), as local knowledge is translated into a classificatory system similar to that used by soil scientists and marine biologists respectively. Whilst Payton et al, in contrast to Aswani and Lauer, do recognise the complexities of the translation process and attempt to reflectively reconcile local and scientific knowledge about soils (Campbell 2002:200), the translation process in both research projects and in the video 'Call of the Country' is controlled by the researchers and determined by the objectives of the research. Despite the reflexivity of Payton et al, the failure of the researchers to acknowledge and investigate the translation process suggests that rather than being solely linked to issues of control and determination on the part of the researchers, this process is 'taken for granted' because of the ontological boundaries foundational to scientific knowledge that make 'nature' a reality, and the associated epistemological privileging of scientific knowledge as a means to access the truth about 'nature'.

The epistemological privileging of science is explicit in the research through the notion of 'ground truth'. According to Raper (1999:63), 'ground truth' assumes a universal conceptualisation of the world whereby a 'real' world (nature) exists independently of culture. Raper argues that this reflects the metaphysical positioning of science, which is revealed through Aswani and Lauer's (2006a:85, 2006b:266) suggestion that the accuracy of local knowledge can be 'ground truthed' or validated scientifically. Similarly, Aswani and Lauer and the Pormpuraaw mapping project rely on GPS technology to represent 'exact location'. As a result, other ways of knowing 'place', for example through kinship, Dreaming stories, relatedness and responsibilities, are positioned as cultural representations of, or beliefs about the 'exact location'. Therefore, whilst local knowledge is prioritised by Aswani and Lauer and is a major focus for the Pormpuraaw mapping project, science remains as the ultimate explanatory methodology that subsequently denies the 'real' explanatory value of local knowledge. Similarly, all of the research projects engage particular processes of generalisation that further privilege scientific knowledge. Generalisation processes mobilise local knowledge so it can be used or understood more widely; they are the specific relationalities that can stand in for various local knowledge understandings (Agrawal 2002:291, Verran 2002:749). Verran (2002:748-749) highlights in her analysis of the alternative firing regimes of scientists and Aboriginal landowners that all knowledge communities have their own ways of generalising, their own relationalities. It is not surprising that the research projects under investigation incorporate scientific forms of generalising. For example, the reliance on 'habitat' expresses a scientific form of generalising whereby all of the various characteristics that are recorded from smaller field-sites and sample areas are generalised as a single entity that takes precedence, that being a 'habitat' (Verran 2005:7-8). Subsequently for the researchers, the local and indigenous knowledge of interest is that which can be made to relate to the particular habitat under investigation. This results in the necessary production of a 'consensus local view' by both Payton et al (2003) and Aswani and Lauer (2006a, 2006b), and is achieved by establishing agreements amongst local informants on what constitutes local knowledge about soils or marine habitats respectively. In this way, 'contradictions' in knowledge are eliminated, and 'properties' are agreed upon to represent the scientifically defined habitat or particular area of interest[6]. Thus ontological boundaries and epistemological privilege underpin the methodology and result in the construction of a database of indigenous or local knowledge that 'makes sense' within a scientific understanding of the world. Further investigation of the research projects reveals an asymmetry based on the embedded assumption that nature and culture are radically distinguished for scientific knowledge and totally overlap for all other knowledges. Whilst the taken-for-grantedness of asymmetry is challenged by an increasing number of social studies of science and technology

[6] Heckler (2007), in her work with Piaroa, points to the criticism she received from other scientists for choosing to work with 'contradictions'. She states that her inclusion of a complex and fluid plant nomenclature was criticised 'as 'ad hoc', thereby implying that [her] findings were not valid'(2007: 96).

(Star and Griesemer 1989; Latour 1987; Turnbull 2000), the underlying principle of asymmetry remains deeply entrenched in much of the social and natural science research. This asymmetry is prevalent in the research by Payton et al (2003) and Aswani and Lauer (2006a, 2006b), expressed through the invisibility of science as a knowledge making practice and the constitution of GIS as a neutral technology. Both of these expressions are implicit in the research and reinforce Latour's (1993:97) assertion that science remains somehow 'unstudiable' as a 'true' representation of nature.

Whilst the processes of local knowledge making are recognised in both projects, the practices of scientific knowledge making are unacknowledged. In particular, Payton et al realise the importance of cultural factors involved in local decision making and highlight that 'farmers' knowledge is not neutral or static but is developed through communication, interpretation and action and is sensitive to particular contexts' (2003:377). However, there is no similar recognition of the need to encompass the broader context of scientific knowledge or to acknowledge the cultural factors embedded within notions of 'development' and 'resource management'. Indeed, the 'messiness' and 'localness' of scientific knowledge making is absent from the research project, as is any revelation of the social context of science. Instead, the scientific research in both Payton et al (2003) and Aswani and Lauer (2006a, 2006b) rely on well-established 'universal' conventions that erase its complexity, contradictions and negotiated character, and contribute to its invisibility and to its authority (Turnbull 1999:3). This process of erasure is even more apparent in the Pormpuraaw mapping project where the 'messiness', 'localness' and negotiated character of scientific knowledge making is visible in the video documentation of the project and yet absent from the textual report (Monaghan and Taylor 1995). The discussions and negotiations between scientists and anthropologists, and with Traditional Owners, to determine the research aims and methodology, and to organise the logistics of equipment, accommodation, and field-site visits are all social practices that impact on the research. The investment of authority in John Taylor is also social, based on his long term association with the people of Pormpuraaw, and on his position within an academic community. The field research happens 'in place', walking on and driving through particular country, recording information about a particular tree or ground coverage or a particular handful of soil. Aspects of the research that are revealed in the video are not detected in the report by Monaghan and Taylor (1995), resulting in the 'written report' becoming an accepted and standardised way of presenting scientific knowledge, and therefore contributing to the invisibility of science as a social activity.

Whilst the actual translation of local or indigenous knowledge into information to be included in a GIS is not really examined by Payton et al (2003) or Aswani and Lauer (2006a, 2006b), the rigmarole associated with producing 'useful' local knowledge is apparent in their research. Indeed, in his brief examination of Payton et al (2003), Campbell (2002:200) points to the 'clear lack of fit' associated with the incorporation of local knowledge into a GIS. In contrast, the relative ease with which scientific knowledge is incorporated into a GIS is made clear through the assumed absence of any need to translate the scientific knowledge into useful knowledge. As the social practice of scientific knowledge making is invisible in the research, subsequently the 'fit' between scientific knowledge and GIS is also left unexamined. As a result, GIS as a technology of knowledge representation is incorporated into the research as a neutral artefact (Turnbull 1999:4). This establishes scientific knowledge as somehow ontologically prior to the cultural overlay of a subjective local knowledge.

Despite stating the obvious, Pickles' comment that 'GIS is far better at incorporating certain types of variable than others' (1999:57) inadvertently maintains the invisibility of scientific knowledge making and the supposed neutrality of the technology. Certainly within the context of asymmetry explored above, it is 'taken for granted' that the researchers only incorporate 'useful' knowledge into the GIS. Consequently, aspects of knowledge embedded within such statements as, 'I own the land I burn', made by a Pormpuraaw Traditional Owner, do not appear in that project's GIS. Similarly, the subjective intentionality attributed to non-human entities by Belyuen women (Povinelli 1995:509), the sentient glacial landscapes of the indigenous people of northwestern North America (Cruikshank 2001:389), and the collective memory knowledge work of Yolngu (Verran and Christie 2007) would struggle to find a place in a GIS. Indeed, relationalities that correspond to those expressed above are not incorporated into the GIS created by the research case studies because the natural world is always and already objectively structured within the database. This results in there being no possibilities for non-human agency, and subsequently no toleration of the 'inconsistencies' and 'contradictions' of local or indigenous knowledge. Therefore within the context of asymmetry, the use of GIS to analyse information results in particular patterns of causal effect relationships that preclude the full complexity of people-environment relationships, specifically those relationships that are not encompassed within a nature-culture dichotomy.

Conclusions

Those aspects of other knowledge traditions precluded from GIS are precisely those relationalities ignored within science that could instigate ecological understanding and indeed contribute to global debates relating to climate change, natural resource use and environmental conservation[7] (Cruikshank 2001:378; Rose 2005:302-303). Whilst collecting 'others' knowledge as classificatory information may 'set the map straight', it also produces more of the same knowledge, representative knowledge, which maintains a separation between nature and culture and situates humans as autonomous actors in the world. However, the relationalities of local or indigenous knowledge traditions often entangle people and things in assertions of agency and responsibility (Cruikshank 2001, Hviding 1996, Povinelli 1995, Rose 2005, Strang 2000). These relationalities situate humans very differently from those within science, prioritising the connections between humans and non-humans. Subsequently, these connections demand a quality of attentiveness that, whilst missing from science, may contribute extensively to ecological understandings.

That GIS technology seriously compromises the integration of diverse knowledges only perpetuates an asymmetry that continues to limit the possibilities for working together diverse knowledges. Instead, the entanglements of humans and non-humans embedded within many local or indigenous knowledge traditions calls forth Latour's concept of natures-cultures. It posits the usefulness of a symmetrical anthropology to reconcile the absence of local and indigenous knowledge traditions from natural resource management and broader scientific ecological debates, and more specifically to consider GIS as an integration domain for diverse knowledges. A symmetrical anthropology takes seriously both the networks of humans and non-humans attended to by many indigenous and local peoples, and the networks of humans and non-humans that proliferate beneath the scientific 'Great Divide'.

7 This is not about perpetuating the romantic notions attached to indigenous peoples and their relationships to the environment. Rather it is about taking seriously the ways indigenous and local peoples construct humans and non-humans so that it may contribute to a better tracing of science and subsequently to a comparative anthropology.

Whilst not explicitly stated by Christie (2005a, 2005b) and Verran and Christie (2007), their approach to knowledge making and database technology can be examined within the guise of a symmetrical anthropology, an approach that facilitates the working together of diverse relationalities. Rather than assume a distinction between sociality and technology, they trace the networks of connections between people, place, knowledge and technology as they are enacted within the context of knowledge making. In this sense, digital technologies are no longer the neutral artefacts as presented within the research case studies of Payton et al (2003) and Aswani and Lauer (2006a, 2006b). Rather, the technologies have agency as they are incorporated within a Yolngu knowledge making tradition. The metaphysical reality of both Yolngu and scientific knowledge traditions are examined symmetrically; the relationalities between sociality and technology are traced. This results in both the revelation of scientific ontological privilege within conventional databases (technology, no longer neutral, has agency), and the subsequent potential to create ontological fluidity within the database that accommodates diverse knowledge traditions.

A symmetrical anthropology would recognise the agency of technology and enable the networks of sociality and technology gathered into a GIS to be traced. Importantly, within a symmetrical anthropology the alignment of technology and sociality becomes problematic. This contrasts with the approach taken in the research case studies whereby the ontological domains of nature and culture implicit in the research predetermine the unquestionable neutrality of the GIS technology on the one hand, and the intense subjectivity of local or indigenous knowledges on the other. The 'taken-for-grantedness' of a non-agential technology (nature) is directly associated with the absence of the relationalities between human and non-human agents embedded within many local or indigenous knowledge traditions, and subsequently limits the potential of GIS as an integration domain for diverse knowledges. Within this context, Christie (2005) and Verran and Christie (2007) demonstrate how to trace the networks gathered into digital technologies, and reveal that an explanation of such networks provides a bases for comparison and subsequently the possibilities for working together diverse knowledges. The ontologically fluid database created by Christie (2005) is an example of how technology could be involved in the working together of diverse knowledges; a potential 'boundary object' creating coherence between diverse knowledge traditions. It is possible that an analysis of GIS focussed on an explanation of the networks embedded within the technology may realise the potential for GIS as an integration domain for the diverse relationalities that constitute human-environment interactions. Therefore, rather than reprimand research scientists for their inability to integrate local and indigenous knowledges within GIS, it is concluded that within a symmetrical anthropology the case studies represent an example of how a scientific community produces networks of natures-cultures, and that the future tracing of the social and technical interactions gathered into GIS may instigate a re-imagining of GIS as an integration domain for diverse knowledges.

References cited

Agrawal, A. 1995. Dismantling the Divide between Indigenous and Scientific Knowledge. *Development and Change* 26: 413-439

Agrawal, A. 2002. Indigenous Knowledge and the Politics of Classification. *International Social Science Journal* 54 (173): 287-297

Aswani, S. and Lauer, M. 2006a. Incorporating Fishermen's Local Knowledge and Behavior into Geographical Information Systems (GIS) for Designing Marine Protected Areas in Oceania. *Human Organization* *65*(1): 81 – 102.

Aswani, S. and Lauer, M. 2006b. Benthic Mapping Using Local Aerial Photo Interpretation and Resident Taxa Inventories for Designing Marine Protected Areas. *Environmental Conservation* 33(3): 263-273.

Bartolo, R. and Hill, G. 2001. A Case Study from Northern Australia: Remote Sensing and GIS Technologies as a Decision-Making Tool for Indigenous Land Management. *Indigenous Knowledge and Development Monitor* 9(1). http://www.nuffic.nl/ciran/ikdm/9-1/bartolo.html (accessed 24th October 2006)

Bradley, J. 2001. Landscapes of the Mind, Landscapes of the Spirit: Negotiating a Sentient Landscape. In R.Baker, J.Davies and E.Young (eds.) *Working on Country: Contemporary Indigenous Management of*

Australia's Lands and Coastal Regions. Melbourne: Oxford University Press.

Campagna, M. 2006. *GIS for Sustainable Development. In M.Campagna (ed.) GIS for Sustainable Development.* London: Taylor & Francis.

Campbell, J.R. 2002. Interdisciplinary Research and GIS: Why Local and Indigenous Knowledge are Discounted. In P.Sillitoe, A.Bicker and J.Pottier (eds.) *Participating in Development: Approaches to Indigenous Knowledge.* London: Routledge.

Chapin, M., Lamb, Z., and Threlkeld, B. 2005. Mapping Indigenous Lands. *Annual Review of Anthropology* 34: 619-638.

Christie, M. 2005a. Aboriginal Knowledge Traditions in Digital Environments. Darwin: Charles Darwin University. http://www.cdu.edu.au/centres/ik/pdf/CHRISTIE_AJIEpaper.pdf (accessed 7th February 2007)

Christie, M. 2005b. Words, Ontologies and Aboriginal Databases. Media *International Australia incorporating Culture and Policy* 116: 52-63.

Cruikshank, J. 2001. Glaciers and Climate Change: Perspectives from Oral Tradition. *Arctic* 54(4): 377-393.

Curry, M. 1998. *Digital Places: Living with Geographic Information Technologies.* London: Routledge.

Deger, L. 2007. Seeing the Invisible: Yolngu Video as Revelatory Ritual. *Visual Anthropology* 20: 103-121.

Descola, P. 1996. Constructing Natures: Symbolic Ecology and Social Practice. In P.Descola and G.Palsson (eds.) *Nature and Society: Anthropological Perspectives.* London: Routledge.

Descola, P. and Palsson, G. 1996. Introduction. In P.Descola and G.Palsson (eds.) *Nature and Society: Anthropological Perspectives.* London: Routledge.

Dorling, D. and Fairbairn, D. 1997. *Mapping: Ways of Representing the World.* Edinburgh: Pearson Education Limited.

Gambold, N. 2001. Participatory Land Assessment: Integrating Perceptions of Country Through Mapping. In R.Baker, J.Davies and E.Young (eds.) *Working on Country: Contemporary Indigenous Management of Australia's Lands and Coastal Regions.* Melbourne: Oxford University Press.

Glowczewski, B. 2005. Lines and Criss-Crossings: Hyperlinks in Australian Indigenous Narratives. *Media International Australia incorporating Culture and Policy* 116: 52-63.

Guiney, M. 1992. Call of the Country. James Cook University.

Haraway, D. 1991. A Cyborg Manifesto: Science, Technology, and Socialist-Feminism in the Late Twentieth Century. In D. Haraway. Simians, *Cyborgs, and Women: The Reinvention of Nature.* New York: Routledge.

Heckler, S. 2007. On Knowing and Not Knowing: The Many Valuations of Piaroa Local Knowledge. In P.Sillitoe (ed.) *Local Science VS Global Science: Approaches to Indigenous Knowledge in International Development.* New York: Berghahn Books.

Hviding, E. 1996. Nature, Culture, Magic, Science: On Meta-languages for Comparison in Cultural Ecology. In P.Descola and G.Palsson (eds.) *Nature and Society: Anthropological Perspectives.* London: Routledge.

Klapproth, D.M. 2004. *Narrative as Social Practice: Anglo-Western and Australian Aboriginal Oral Traditions.* Berlin: Mouton de Gruyter.

Latour, B. 1987. *Science in Action: How to Follow Scientists and Engineers Through Society.* Cambridge: Harvard University Press.

Latour, B. 1988. Mixing Humans and Nonhumans Together: T*he Sociology of a Door Closer. Social Problems* 35(3):298-310

Latour, B. 1993. *We Have Never Been Modern.* Cambridge: Harvard University Press.

Latour, B. 1998. From the World of Science to the World of Research? *Science 280*(5361):208-209.

Longley, P.A., Goodchild, M.F., Maguire, D.J., and Rhind, D.W. 2005. *Geographical Information Systems and Science.* New York: John Wiley & Sons, Ltd.

McCall, M.K. and Minang, P.A. 2005. Assessing Participatory GIS for Community-based Natural Resource Management: Claiming Community Forests in Cameroon. *The Geographical Journal* 171(4): 340-356.

Meyers, F. 1986. *Pintupi Country, Pintupi Self: Sentiment, Place and Politics among Western Desert Aborigines.* Berkeley: University of California Press.

Monaghan, J. and Taylor, J. 1995. Traditional and Current Land Use in the Pormpuraaw Community. In J.Cordell (ed.) Indigenous Management of Land and Sea and Traditional Activities in Cape York Peninsula. (Cape York Peninsula Land Use Strategy) University of Queensland.

Nader, L. 1996. Anthropological Inquiry into Boundaries, Power, and Knowledge. In L. Nader (ed.) *Naked Science: Anthropological Inquiry into Boundaries, Power, and Knowledge.* New York: Routledge.

Newman, C.M. and LeDrew, E. 2005. Towards Community- and Scientific-Based Information Integration in Marine Resource Management in Indonesia: Bunaken National Park Case Study. *Environments Journal* 33(1): 5-24.

Payton, R., Barr, J., Martin, A., Sillitoe, P., Deckers, J., Gowing, J., Hatibu, N.,

Naseem, S., Tenywa, M., and Zuberi, M. 2003. Contrasting Approaches to Integrating Indigenous Knowledge about Soils and Scientific Soil Survey in East Africa and Bangladesh. *Geoderma* 111: 355 – 386.

Pickles, J. 1999. Arguments, Debates, and Dialogues: GIS – Social Theory Debate and the Concern for Alternatives. In P.Lomgley, N.Goodchild, D.Maguire, and D.Rhind (eds.) *Geographic Information Systems: Principles and Technical Issues.* Volume 1. New York: John Wiley and Sons Inc.

Pickering, A. 1992. From Science as Knowledge to Science as Practice. In A. Pickering (ed.) *Science as Practice and Culture.* Chicago: The University of Chicago Press.

Povinelli, E. 1995. Do Rocks Listen? The Cultural Politics of Apprehending Australian Aboriginal Labour. *American Anthropologist* 97(3): 505-518.

Raper, J. 1999. Spatial Representation: the Scientist's Perspective. In P.Lomgley, N.Goodchild, D.Maguire, and D.Rhind (eds.) *Geographic Information Systems: Principles and Technical Issues.* Volume 1. New York: John Wiley and Sons Inc

Robiglio, V., Mala, W.A. and Diaw, M.C. 2003. Mapping Landscapes: Integrating GIS and Social Science Methods to Model Human-nature Relationships in Southern Cameroon. Small-scale Forest *Economics, Management and Policy* 2(2): 171-184.

Rose, D.B. 1992. *Dingo Makes Us Human: Life and Land in an Australian Aboriginal Culture.* Cambridge: Cambridge University Press.

Rose, D. 2005. An Indigenous Philosophical Ecology: Situating the Human. *The Australian Journal of Anthropology* 16(3):294-305.

Sappington, N. 2003. Geography and GIS: Serving Our World. ESRI Map Book Volume 18. Redlands: ESRI.

Scoones, I. 1999. New Ecology and the Social Sciences: What Prospects for a Fruitful Engagement? *Annual Review of Anthropology* 28:479-507.

Shapin, S. 1994. *A Social History of Truth: Civility and Science in 17th Century England.* Chicago: University of Chicago Press.

Sillitoe, P. 1998a. Knowing the Land: Soil and Land Resource Evaluation and Indigenous Knowledge. *Soil Use and Management* 14: 188-193.

Sillitoe, P. 1998b. The Development of Indigenous Knowledges: *A New Applied Anthropology. Current Anthropology* 39(2): 223-235.

Star, S.L. and Griesemer, J.R. 1989. Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. Social Studies of Science 19: 387-420.

Strang, V. 2000. Showing and Telling: Australian Land Rights and the Material Moralities. *Journal of Material Culture* 5(3): 275-299.

Strang, V. 2005. Water Works: Agency and Creativity in the Mitchell River Catchment. *The Australian Journal of Anthropology* 16(3): 366-381.

Strathern, M. 1996. Cutting the Network. J*ournal of the Royal Anthropological Institute* 2(3): 517-535.

Taylor, J. 1984. Of Acts and Axes: An ethnography of Socio-cultural Change in an Aboriginal Community, Cape York Peninsula. Unpublished PhD Thesis. James Cook University, Townsville.

Taylor, P. 1990. Editorial Comment: GKS. *Political Geography Quarterly* 9(3): 211-212.

Taylor, P. and Overton, M. 1991. Further Thoughts on Geography and GIS. *Environment and Planning A* 23:1087-1090.

Turnbull, D. 1997. Reframing Science and other Local Knowledge Traditions. *Futures* 29(6): 551-562.

Turnbull, D. 1999. GIS and Indigenous Knowledge: Conflicting Ways of Place and Space Making. Paper presented at 'Intersections: Society, Technology and Geographic Thought'. Lexington, Kentucky.

Turnbull, D. 2000. *Masons, Tricksters and Cartographers: Comparative Studies in the Sociology of Scientific and Indigenous Knowledge.* London: Routledge.

Verran, H. 1998. Re-Imagining Land Ownership in Australia. *Postcolonial Studies* 1(2): 237-254.

Verran, H. 2002. A Postcolonial Moment in Science Studies: Alternative Firing Regimes of Environmental Scientists and Aboriginal Landowners. *Social Studies of Science* 32(5-6): 729-762.

Verran, H. 2005. Knowledge Traditions of Aboriginal Australians: Questions and Answers arising in a Databasing Project. Making Collective Memory with Computers, Charles Darwin University. http://www.cdu.edu.au/centres/ik/pdf/knowledgeanddatabasing.pdf (accessed 7th February 2007)

Verran, H. and Christie, M. 2007. Digital Technologies and Aboriginal Knowledge Practices. Making Collective Memory with Computers, Charles Darwin University. http://www.cdu.edu.au/centres/ik/pdf/DigTech_IndigPlaceAust.pdf (accessed 7th February 2007)

Watson, H. 1993. Aboriginal Australian Maps. In D. Turnbull (ed.) *Maps are Territories: Science is an Atlas.* Chicago: University of Chicago Press.

Watson-Verran, H. and Turnbull, D. 1994. Science and Other Indigenous Knowledge Systems. In S. Jasanoff, G. Markle, J. Petersen, and T. Pinch (eds.). *Handbook of Science and Technology Studies.* London: Sage Publications.

Williams, S. 2005. Participatory Research to Incorporate Indigenous Knowledge into NRM. Riprap 28: 26-27. http://www.rivers.gov.au/acrobat/riprap28.pdf (accessed 6th February 2007)

WinklerPrins, A.M.G.A. 1999. Local Soil Knowledge: A Tool for Sustainable Land Management. *Society and Natural Resources* 12: 151-161.

WWF (World Wildlife Fund) 2001. Innovative GIS Project Model for the Natural and Cultural Mapping of Wetlands. http://wwf.panda.org/ (accessed 7th August 2006)