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UNDERSTANDING THE RELATIONSHIPS BETWEEN SOCIETY AND ENVIRONMENT IN GEOGRAPHY WITH GIS SUPPORT

[1]Sailajananda Saikia and [2]Bishmita Medhi
[1]Assistant Professor, Department of Geography, M.C. College, Barpeta
[2]Research Scholar, Department of Geography, NEHU, Meghalaya
[1]s.sailajananda@gmail.com, [2]Bishmita.elsa@gmail.com

Abstract: The environment of the Earth has many close connections and relationships with human activity. It is also now more widely recognized that a profound transformation of the Earth's environment is taking place and that many of these changes are the result of human action. Intensification and diversification of resource use, globalization, growth in population, as well as patterns of population distribution and migration, and changing flows of information, products and technology, have produced changes in landscapes and ecosystems of the Earth's surface.
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Introduction

It is now nearly forty years since the `Quantitative Revolution' in geography led to the first systematic attempts to structure and understand digital data that are geographically referenced. Today, the volume of available digital data, and the processing power of the computer hardware to analyse it, is simply mind-boggling by even the standards of the recent past. GIS is an umbrella term for the technology which has been successfully used to create, manage and analyse spatial data in these rapidly-changing times. An attempt has been made through this paper to assess some of the impacts of GIS on (human) geography as a discipline and its role in scientific problem-solving; and assess the existing and potential symbiosis of quantitative geography and GIS. The context to these comments is our emergent `digital world' - in which everyday actions and behaviour patterns may be captured and used to create computer-based models of reality.

The outreach of quantitative geography and GIS

The term `quantitative geography' describes a wide range of conceptual, model-based and statistical approaches to spatial science, statistical modelling and locational analysis (Taylor and Johnston 1995). These have been used in the quest for scientific generalisation, and have remained a sustained focus of interest in a discipline which has probably experienced more than its fair share of changes in academic fashions during the last forty years (Fotheringham et al. 2000). More recently, the quantitative geography paradigm has developed the capacity for comparisons across space and time in a manner which is at the same time nomothetic and context-sensitive (see also Jones 1991). Today quantitative geography is relevant, (e.g. Cli¨ and Haggett 1993), applicable (e.g. Bailey and Gatrell 1995) and commercially applied (e.g. Birkin et al. 1996). Yet this essentially triumphalist view of the specialism is far from universally shared across the discipline. Some geographers have argued that method and technique is not itself a tenable focus of interest (cf. Openshaw 1991), while others (e.g. Sayer 1979; Curry 1995) have expressed serious doubts that a technological system can ever generate significant insights into significant problems of geographical concern. Partly as a consequence of successive waves of critique, quantitative approaches accounted for a steadily decreasing real share of intellectual activity in the subject during the 1970s and early 1980s. The skill base of quantitative geography has left its protagonists with a range of applicable skills, most all of which might be used in a GIS environment, yet that skill base has become narrower at the disciplinary level over time.

The innovation of GIS into geography came at a time when Thatcherite and Reaganite policies were placing stringent short term demands for relevance and real world application upon academia in general, and social science in particular. In the changed political economy of research grant allocations that ensued, GIS-centric programmes in the UK, US, Netherlands and Sweden (amongst others) fostered `near-market' research, to varying degrees. Faced with often swinging cuts in traditional block grant resource systems, such research also offered the prospect of external sponsorship and thus a means for maintaining research programmes - albeit usually in a piecemeal fashion. In these new circumstances, GIS was catalytic to maintenance of a mainstream role of geography in Europe, and demonstrated the subject's relevance to a more sceptical American community. Additionally, the co-habitation of quantitative methods with `real world' application generated a small number of conspicuous successes - notably the GMAP consultancy at the University of Leeds (UK), which grew to employ over 100 people in extra-university funded spatial analysis work (Birkin et al. 1996). And yet, perhaps because of these `near market' pressures, GIS-based initiatives have not been preoccupied with the more strategic spatial analysis agenda that has characterised the quantitative geography paradigm.

Whilst this suggests a `successful' academic role for GIS in applied geography research, the practice of GIS in academic geography has been guided by some rather different priorities. In the early days of GIS, it was curious that there was no close isomorphism between a successful approach to systematic scientific analysis in geography, and a successful geographical data handling environment. We can look towards the ways in which GIS technology has developed and been disseminated to account for the dislocation of the two communities.

Historically, the techniques of quantitative geography were borrowed from neighbouring disciplines (inter alia social statistics, econometrics, botany and zoology) and adapted to explicitly spatial contexts. As Fotheringham et al. (2000) note, there has been progressive `import substitution' of generic spatial techniques over time (e.g. Cliff and Ord 1973; Getis 1991) to the point at which geography is poised to become a net exporter of quantitative expertise. Within this broad picture, the detail of quantitative geography research has been characterised by both continuity and change. Continuity has been exemplified by research into spatial interaction (e.g. Birkin et al. 1996) where successive respecification and reformulation of models over more than thirty years has culminated in the current generation of predictively-successful, data rich models for business and service planning. Change is illustrated by the trend away from crudely-specified system-wide models, reliant upon very imperfect and/or inappropriate data, towards much better tailored, yet partial, models which integrate a rich range of digital data sources (Longley and Harris 1999). As an increasing proportion of the world of experience can be captured and represented using digital technology, so quantitative geography has also become more aware of complexity, relativism and sensitivity to context.

By contrast, although GIS has from the outset been an explicitly spatial technology, it is one that has been developed by computer scientists whose programming interests have centred upon the development of layer and more latterly object-orientated data models. Dissemination of GIS into geography has been through the medium of proprietary computer packages which, while well attuned to a wide range of commercial applications, use the spatial medium for depicting results but not for structuring analysis. The GIS industry is huge (Longley et al. 1999 described it as a business worth over $12bn with over 500,000 regular users) and is comprised of inter-linked hardware, soft-ware, data services and consultancy components. The `G' in GIS has led some geographers to feel that the discipline has some kind of proprietary interest in the subject, yet it is important to remember that (cartographic design work aside) geographers have actually played a negligible role in the development of most proprietary systems. It seems rather disingenuous for geographers to speculate `what kind of distortion will result…if the discipline strives to retain a central role in [the] emerging

[GIS] ``profession'' ' (Pickles 1995: 4; emphasis added) because geography has never been central to the development of GIS. Indeed, the general skill base of geography is today such that many of its practitioners are unable to take an informed insider's view of the remit and use of GI technologies in the 21st century.

Understanding the Relationships between Society and Environment in Geography with GIS Support:

GIS is a much-vaunted career destination for geography graduates, yet they are employed in application and/or marketing of GIS rather than system development. GIS has also become successfully established in the geography curriculum, no doubt because of external imperatives to offer relevant and transferable technical skills. The burgeoning interest in GIS has sometimes given the impression that acquaintance with the operating systems of proprietary GIS products is a valid end in itself. In forming a view of the world through the lens of a particular proprietary system, the intellectual focus can change from identifying the message of spatial analysis to mastering the command structure of a particular software medium. Thus, paradoxically, the upsurge in interest in GIS may actually accelerate de-skilling within the discipline of geography (Clarke et al. 1995).

The environment of the Earth has many close connections and relationships with human activity. It is also now more widely recognized that a profound transformation of the Earth's environment is taking place and that many of these changes are the result of human action. Intensification and diversification of resource use, globalization, growth in population, as well as patterns of population distribution and migration, and changing flows of information, products and technology, have produced changes in landscapes and ecosystems of the Earth's surface. They also raise questions about the capacity of environmental systems to sustain change and support life. Land use and land cover changes have most recently been recognized as both centrally important causes and consequences of environmental change, and to have influence at geographic scales ranging from the local to global and time scales from short to long.

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Over the last decade an international research program, the Land Use and Land Cover Change Program (LUCC), and related series of local, regional and national programs and projects have examined the patterns and processes of land use and land cover change. Some patterns of change are well known as global phenomena, for example desertification and tropical deforestation. Other changes are more local, but nonetheless familiar and with important consequences and impacts, for example residential development and urban sprawl. A wide variety of processes that produce these changes have also been documented. These represent a mix of environmental, social, economic, political, institutional and technological forces. Underlying forces include climate factors, national policies, for example on trade, and population growth. More immediate causes include human activities at local scales, including cropland expansion, development of transportation network, changes in markets, resettlement and wood extraction for fuel.

Many studies of land use and land cover change have used the data management and analytical power of GIS, frequently combined with the data collection capacity of remote sensing instruments and GPS.GIS and remotely sensed imagery have been used to map the extent of change at local, regional, national and global scales.GIS has also helped to gain insights into the current and recent condition of land use and land cover in the landscapes, environments, communities and places where changes have occurred. For example, GIS offers the capability of coupling a time series of data developed from remotely-sensed images that document change in land cover, with maps of transportation networks, markets and population distribution that describe how people use the landscape and land resources. This description of the coupled human and environmental system for a specific place can in turn be linked with surveys and other spatially detailed inventories of human preferences, decisions and actions to make models of change. Models describe environmental processes and human decision-making, and, when linked to GIS, help with analysis and development of understanding of the behaviour of land use as a reflection of coupled natural and human systems.

In many ways, therefore, GIS is the central technology in the science of land use and in study of society's interactions with environment. Alongside GIS, geography offers a unifying suite of intellectual tools that encourage the interdisciplinary thinking that underpins evaluation of coupled social and natural systems. Spatial thinking is at the core of understanding change over time and variability across space, and of relating social systems to environmental systems. Although social and environmental science each provide general principles that guide our understanding of social and natural systems separately, the use of geographic location as a referencing system and a geographical understanding of place provide a framework that allow them to be related.

Studies of the geography of land use and land cover changes are thus made possible by the power of geographic location in GIS which can relate descriptions of very different aspects of the socio-economic and environmental landscape. Used appropriately, GIS also supports place-based explanation of the modification of landscapes by human action. The product is a better understanding of the mutual interaction between human activity and change in environmental systems. This is important not only for understanding the patterns of land use and land cover produced over recent and longer-term history, but also for identifying trajectories of change in response to the processes that produced change, and for predicting what might happen in the future.

A new international program representing an important extension and refocusing of the last decade's work on land use and land cover change has recently started. The Global Land Project is a core program of the International Geosphere-Biosphere Program and International Human Dimensions of Global Environmental Change Program. The Global Land Project will combine study of the dynamics of land systems and an understanding of the consequences of land system change with efforts directed at increasing our knowledge of sustainability of land systems, and their vulnerability and resilience in response to hazards and disturbance.

The Global Land Project builds on the LUCC program by integrating the interdisciplinary science of land use and land cover change with ecosystem science that focuses on the description, maintenance, and enhancement of ecosystem services. The objectives of Global Land Project include identifying the nature of change in coupled natural and human land systems, assessing how ecosystem services are affected by changes, and to identify the character of vulnerability and sustainability in land systems. Ecosystem services describe the benefits obtained from regulation of ecological processes manifest in climate and weather regulation, disease control and flood control. Taken together, study of land use change and ecosystems services provide an opportunity to gauge the sustainability of coupled human and environmental systems at a range of geographic scales and over a variety of time periods.

GIS and other geographic technologies will be central to both the science and success of the Global Land Project. Ecological change has a strong geographic component and is influenced by the spatial configuration and geographic context of ecological processes operating at a range of scales.GIS provides the opportunity to link description of ecological systems and models of ecological processes, with descriptions of land systems and the social and environmental processes that influence their development and trajectories of change in space and time. The measurement of ecosystem services to identify biological, social economic and other values presents an opportunity for imaginative thinking that combines the intellectual contents of ecology, geography and a variety of other disciplines, but the technical expertise, analytical skills, and the capacity for synthesis of GIS specialists.

Extending this integration of intellectual and technical expertise to focus on sustainability, resilience and vulnerability provides a fresh challenge. However, it is a challenge that gives geography, and geographical technologies, a strong practical relevance as economic development, population growth and land use changes continue, in the face of continued environmental changes and hazards.

Conclusion

To highlight just a few of the ways in which the academic success of GIS in geography differs from that of the subject's earlier `Quantitative Revolution'. The medium of GIS must not be allowed to overwhelm the messages of spatial analysis. The problem is not that GIS cannot credibly be used in the widest range of research applications, for it is a demonstrably successful, if routine, technology in this regard. The spatial analysis skill base within geography is narrow, and there are dangers if proprietary software is rapidly assimilated into a discipline which lacks clear direction as to how it should `add value' to these developments (see Longley 1998 for a discussion of the emergence of geo computation in this context). Second-hand software, inexpert use and mundane or misguided application are not ingredients of a healthy scientific discipline, and uncritical application can deflect resources from other, potentially more valuable, research pursuits. Geographers have largely been passive observers of the development of proprietary GIS, yet it is in the use of GIS as a tool for spatial analysis in the digital age that geographers are likely to demonstrate their worthiness in terms of cumulative academic activity. GIS is changing too, and the replacement of monolithic systems with reusable software modules and networked environments will allow use of GIS to reinforce our increasingly sophisticated understanding about the nature of spatial analytic conundrums and problems.

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