Is GIS appropriate technology?

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Abstract. Appropriate technology(AT) has become an integral part if the programmes for decentralized regional development in the third world appropriate techniques are usually low in capital costs- they can be maintained without a high level of expertise, and they do not involve patents, expensive copyrights and royalties. By these criteria a commercial geographical information system(GIS) is not an appropriate technology to be used in decentralized development. However, the use of local renewable resources involves the adoption of end-use analysis for matching end – uses to specific sources so as to minimize the consumption of material and energy (i.e. minimize entropy). This matching requires an inverse increase in information which leads to what may be called the information-entropy trade-?; minimization of entropy requires an inverse increase in information. In this respect computers and GIS have an important contribution to make to decentralized regional planning. Drawing on a case study in Sri Lanka, this paper presents some ideas on how to incorporate GIS into local-level planning information systems.

1. Introduction

The theory and practice of economic development of the Third World are on the throes of a deep crisis. The poor nations owe the Western banks over US $ 1000 billion in external debt. Several Third World nations now spend a large part of their export earnings on simply paying interest on the debt. Some nations are being loaned more money to pay interest so that they would not default on previous loans. The debt burden affects those who live at marginal levels of subsistence in a disproportionate way. As part of an emerging alternative paradigm there is a new interest in decentralized regional planning and development, in using locally-available resources and in low-cost appropriate technology (AT). In addition there is a growing interest expressed by local-area planning authorities in the Third Word in acquiring computers and software for mapping and for geographical information systems (GIS). At first glance such systems appear to be clearly inappropriate technology because of their high cost in equipment, software, training and consulting fees. These systems are also antithetical to the principle of fostering local self-reliance and reducing external dependencies. However, the concept of using local resources is not a simple exercise resources come into being contextually in a system of space and time coordinates embedded in the local regional geography. Uncovering these local resources is an information-intensive exercise. From this point of view one can argue that GIS tools are an essential part of regional development through the use of AT. This paper explores the theoretical issues by using a framework called end use rationality and also gives a brief report on a project being implemented in Sri Lanka as an effort to develop GIS as an appropriate technology

2.Conceps of appropriate technology

in the early 1960s E. F. Schumacher began to write on the critical role of technological choice in economic development. Drawing on his field visits to Burma and India, he formulated his now famous concept of intermediate technology, a kind of technology which would be more efficient and scientific than the very low-level technology being use throughout rural parts of the Third World, but very much simpler, cheaper and easier to understand and maintaining than the sophisticated, high technology of the West (Schumacher 1973). Since then the concept has been expanded and restated as AT to include sustainable agriculture, preventive health care, low-cost building construction and so on (Dorrow and Saxenian 1986, Congdon 1977).

Despite enthusiastic endorsements by important public figures and the large numbers of books written on the subject, the actual progress in the development and diffusion of an appropriate to date has been quite modest. Estimates of the total cash value of AT are difficult to make and are unreliable. An estimate made for total activities in 1977, which include world-wide research and development, dissemination of information, promotion, lobbying and establishments of enterprises, put the value at US$1000 million. That was still less than 0-015 per cent of the world's gross national product in 1977, and a hundred times less than world-wide expediters on research and development that year (Jequier and Blanc 1983, p-. 65). Another of the radio of research and development in AT to that of modern technology put in at the staggering number of 1 to 12000 (Bhagavan 1979, p.11). according to still another account of the total value of all newly-designed equipment promoted as AT and sold in the Third World in 1985 was less than US$100 million (Darrow and Saxenian 1986, p. 10). In the early 1980's, funding was cited by AT organizations as one of the key factors limiting their long-term development (Jequier and Blanc 1983, p.78)it is difficult to know what to make the differing estimates, but there is no much doubt that the total amount of money spent on the development of AT is still quite modest.

There are several reasons for the slow progress in the development of AT and its diffusion. Western companies (which are also leading innovators with their large research and development budgets) naturally which to sell to the poor countries only the technologies that are already development and readily available. The technology transferred to the developing countries by large multinational companies has been designed for conditions of abundant capital and scarce labor. This technology is not capable of providing jobs for large numbers of people because because it was designed to do the opposite- to save labor by using capital. It is financially unattractive, perhaps even risky, for private companies to develop new untried technology that are specifically tailored to the needs of the poor countries. Official developments agencies in the West to spend a promotion of their resources on the development of small scare technology but some of them, being national agencies, are mandated to promote the business interests of the national companies (Jequier and Blanc 1983, Lappe et al. 1987). On the other hand, government leaders of poor

countries who are publicly supportive of AT have provided very little real resources. Corrupt officials often discourage the promotion of cheap, small-scale technology because such development limits the opportunities for receiving lucrative commissions and graft. Additionally, there is also a widespread belief that simple, small-scale technology is traditional, inefficient and inferior to modern high technology.

3. the need of a review of AT

today there is real need to look at AT very seriously in a comprehensive way. We need to be concerned with not only the engineering of new techniques but also the problems of community acceptance and participation. The new urgency to review and incorporate AT springs from the continuing crisis in the theory and practice of economic development. Despite four decades of development efforts there is a persistent lack of basic goods in the Third World as reflected by the chronic protein-calorie malnutrition of nearly a fifth of the world's population. Even by conventional criteria of growth in GPD, the developing countries are performing very poorly, their growth rates dropped from a average of 5-4 per cent during 1973-1980 to 3-9 per cent for 1980-1987 (World Bank 1988, p. 23). The total Third World external debt in 1987 stood at over a thousand billion US dollars (Gearge 1988, pp. 11-29). In recent years rising debt service and a cut in lending has led to a reversal of net resource transfer to the developing countries, totaling over US$85 billion (World Bank 1988, p. 29). Several poor countries spend from a fourth to a half of their export earnings simply paying interests on long term debt (World Bank 1988, pp. 256-257). The working and the non working poor in the developing countries pay a heavy share of the debt burden, with IMF- mandated austery drives there are inevitable cutback in food subsidies, children's nutrition and other welfare programmes for the poor (George 1988). A large part of the external debts occurred in what is described as ' developments loans' , despite the fact that the projects may bear little relation to the eradication of mass poverty (Gran 1983).

In the light of worsening conditions in the physical quality of life in world's poor it is important to give serious consideration to the ideas of the proponents of AT who claim (rather convincingly) that there are known methods in agriculture, nutrition, industry, health care, education, building construction and transport whereby basic human needs can be met using local resources and very little external capital (see the hundreds of publications reviewed in Appropriate Technology Sourcebook(Darrow and Palm 1978, Darrow and Saxeian 1986); The Next Whole Earth Catalog; Village Technology Handbook(1981); Rainbook : Resources for Appropriate Technology, (1977); and the quarterly journal of the Intermediate Technology Development Group, Appropriate Technology).

Several countries in Asia, Africa and Latin America have now adopted policies for regional decentralization of development administration. Almost immediately after her independence, India was one of the first countries to recognize formally the importance of local government. In 1972, Philippines adopted a comprehensive progamme of regional planning with the objective of decentralizing decision- making to the regional level, with the activities or line agencies co-ordinated by the National economic Development Authority

(NEDA). Among other notable efforts towards the decentralization of development planning are the apazilla administration in Bangladesh (Kan 9186), the changwat scheme in Thailand, the district-level Integrated Rural Development Programme in Sri Lanka (Dias and Leelasena 1983, Rao et al, 1983,Yapa 1988, and regional programmes in Tanzania and Sudan (Rondinelli et al.1983). Indeed, the practical implementation of regional decentralization in the developing countries can be feasible only if we begin to work with low-cost technology that uses local resources (Darrow and Saxenian 1986).

Today one of the frequent budget requests made by planners in the Third World is for resources for computer hardware and software for use in database management, spreadsheet analysis and word processing. Correspondingly, in regional and local-area planning offices requests are routinely made for map display devices, software for map analysis and GIS, and training in the use of software. Given the important role of AT in decentralized regional development it would be most useful to examine the request for automated map making and GIS to ascertain if their use is compatible with the principles of AT.

4. Criteria for appropriate technology

AT is not a clearly; in fact, it covers several in somewhat distinctive ideas that include the terms 'intermediate', 'low-cost', 'soft', 'alternative', and 'appropriate'. The term 'intermediate' lays stress on engineering aspect, and technology is defined as being somewhere between modern and traditional. The 'low-cost' approach looks primarily at economics factors. 'Soft' technology is an idea that was developed in the industrially-advanced countries as a solution to the ecological degradation wrought by modern high-energy and chemical technology. The term 'alternative' is commonly used to describe techniques that differ from modern technology in agriculture, energy systems and health care. The term 'appropriate', which covers all of these ideas,… is the most fluctuating in time and space, and heavily influenced by value judgements and ideological considerations'(Bhagavan 1979, p.8). I shall employ the term 'appropriate' throughout this paper because what constitutes appropriate technology is indeed specific to time , place and purpose , and it may well include what we term 'modern'.

I shall describe criteria for AT by drawing on the attributes suggested by a few of its proponents. First is a list of features provided by Darrow (Darrow and Pam 1978, p. 11); Ats:

1) are low in capital costs;
2) use local materials whenever possible;
3) create jobs, employing local skills and labor;
4) are small enough in scale to be affordable by a small group of farmers;
5) can be understood, controlled and maintained by villagers whenever possible, without a high level of Western-style education;
6) can be produced out of a small metal-working shop, if not in a village itself;
7) suppose that people can and will work together collectively to bring improvements to their communities; recognizing that in most of the world important decisions are made by groups rather than by individuals;

8) involved decentralized renewable energy sources, such as wind power, solar energy, water power, methane gas, animal power and pedal power (such as in that highly-efficient machine, the bicycle);

9) make technology understandable to the people who are using it and thus ideas that could because in further innovations;

10) are flexible so that they continue to be used or adapted to fit changing circumstances;

11) do not involve patents, royalties, consultation fees, import duties, shipping charges or financial wizards; practical plan can be obtained free or at low cost and no further payment is involved.

The four following propositions are from Shumacher writing on AT for development in the Third World (1973, pp. 175-176):

1) that workplaces have to be created in the areas where the people are living now, and not primarily in the metropolitan areas in to which they migrate;

2) that these workplaces must be on average, cheap enough so that they can be created in a large numbers without this calling for an unattainable level of capital formations and imports;

3) that the production methods employed must be relatively simple, so that the demands for high skills are minimized, not only in the production process itself but also in matters of organizations, rae material supply, financing, marketing and so firth; and

4) that production should be mainly from local material and mainly for local use.

Schumacher argued that, for these requirements to be satisfied, two conditions should be met: first in the adoption of a 'regional' approach to development, and second is the design of an 'intermediate technology'.

Finally, I shall quote from Lovins on attributes of soft technology taken from his views on future energy policies for the US (1977, pp.38-39).

1) They rely on renewable energy flows that are always there whether we use them or not, such as sun and win, and vegetation, on energy income, and not on depletable energy capital.

2) They are diverse, so that as a national treasury runs on many shall tax contributions, so national energy supply is an aggregate of very many individual modest contributions, each designed for maximum effectiveness in particular circumstances.

3) They are flexible and relatively low technology – which does not mean unsophisticated, but rather easy to understand and use without esoteric skills, accessible rather than arcane.

4) They are matched in scale and in geographic distribution to end-use needs, taking advantage of the free distribution of most natural energy flows.

5) Thy are matched in energy quality to end- use needs (I shall comment later on Lovins' notion of energy quality and end-use needs).

These statements represent three approaches to the topic of technology as reflected in the terms, 'appropriate, 'intermediate, and 'soft'. Several difficulties arise in using this definitions to evaluate the role of GIS in Third World development. First, the attributes the AT described by Darrow, Schumacher and Lovins concern the nature of production technology that uses material and energy; their descriptions contain no explicit reference to information

technology, and GIS is about the processing of information. Second, unlike matter and energy, information does not follow the first and second law of thermodynamics. This amplies that many of the statements made about AT do not apply to information technology such us GIS. Third ,GIS exhibits a dual character with respect to AT –it complements some attributes and contradicts several others. The remainder of the paper is an exploration of the dual character of GIS in is relation to AT.

5 Notes on GIS

A GIS is a computerized database for coding storing and retrieving information tied to a geographic coordinate system or a set of places. The primary function of the GIS is the combination and evaluation of different map overlays for the purpose of providing new composite information. Additional functions of GIS include the digital storage of map data, the production of maps and graphic displays and the reporting of statistical summaries. GIS has three important components computer hardware, application software and a proper organizational context(Burrough 1986). The hardware consists of the central processing unit(CPU), the monitor, the disk drive storage, a printer/plotter output device and a digitizer to convert coordinate data from maps into a digital form that can be used by the3 computer. There is a wide range of devices that can be used to fill these hardware requirements. A minimum microcomputer workstation with a computer, digitizer, a printer and a plotter can be installed for about USS10 thousand. Although this may appear to be a modest sum of money it is still beyond the financial means of most local-area planning offices in the Third World.

The GIS software modules have five components (Burrough 1986)(a) data input and storage;(b) data storage and database management;(c) data output and presentation;(d) data transformation; and (e) interaction with the user. I shall describe only the fourth component because the meanings of the others are self-evident. Component (d) on data transformation involves the large array of methods that can be applied to the data in ordener to answer the queries asked of GIS. These include the transformations for use in scale-changing logical retrieval of data, calculations of areas and perimeters which are usually found in every type of GIS. Other transformation have very specific applications, such as network analysis and optimum location of facilities. Most good GIS will allow the user to make queries and interact with the system in a natural language.

According to Burrough the third component of a GIS system is the appropriate organizational context:

In order to be used effectively, the GIS needs to be placed in an appropriate organizational context. It is simply not sufficient for an organization to purchase a computer and some software and to here or retrain one or two enthusiastic individuals and then to expect instant success. Just as in all organizations dealing with complex products, as in manufacturing industry, new tools can only be used effectively if they are properly integrated into the whole work process

and not tacked on as an afterthought. To do this properly requires not only the necessary investment in
hardware and software, but also in the retraining of personnel and managers to use the proper organizational context(Burrough 1986,p 10).
Burrough's notion of the appropriate organizational context for the success of GIS can be usefully expanded to include the infrastructure necessary to support microcomputer systems in rural planning offices in the Third World. This includes several components :(a) access to electric power lines or owning generators to produce power locally;(b) i9ntermediate power units to smooth the all-too-common fluctuations in voltage;(c) convenient access to computer stores for service, repair and supply of material; and (d) occasional access to software problem solving.
GIS which started out as mainframe and minicomputer-based tools are today moving more and more into the less expensive microcomputer marker. According it the February 1989 issue of Computer Graphics Review the market in the United States for personal computer mapping systems grew from USS37 million in 1987 to USS57 million by late 1988. The frontrunners in these growth were Environmental Systems Research Institute's(ESRI) PC ARC/INFO and AutoDESK's CAD `package AutoCAD(Anon,1989).
PC ARC/INFO is one of the most sophisticated GIS packages available for microcomputers. It has been described as a "tool box" of general-purpose GIS programs for processing maps in a vector format. The tools include   programs for digitizing map editing, overlays, creating buffers around chosen geographic features, map generalization, report generation and converting maps from ARC/INFO to other formats.
ARC/INFO consists of two subsystems:
(1)ARC is a set or programs for the management of locational coordinates or geographic features (points, lines and polygons) which are stored and processed in vector format.
(2)INFO, which handles the thematic data processing, is a relational database management system. It is a commercial database management system which has been linked to the map editor ARC

The cost of PC ARC/INFO(about USS15000) makes it currently inaccessible to a large number of potential users among students, teachers and professionals working in small planning offices in the US and in the developing countries. To the cost of the software must be added the cost of the hardware (about USS10000) and the cost of training personnel in the use of ARC/INFO which may amount to several thousand dollars if expatriate consultants and staff are involved.
According to the criteria of AT given earlier by Darrow it is difficult to see how a GIS system such as PC ARC/INFO can be described as an appropriate technology. Small planning offices in the rural areas of the Third World cannot afford the capital costs of PC ARC/INFO. It is mot a technology that "....can be understood, controlled and maintained by villagers whenever possible, without a high level of Western-style education". It is strictly copy protected; its use requires consultation and training, and fees for such services. Also a significant

portion of these costs involves foreign exchange. These comments are nor intended as a criticism of PC ARC/INFO; rather they refer to the problems of adapting a software system that was designed for the needs of industrially-advanced countries to the conditions of the Third World. Notwithstanding the validity of these observations related to initial and recurring costs, it can be argued that in the long run GIS can become a very cost effective and appropriate technology given the central role   information plays in the implementation of AT. The argument that GIS can be appropriate technology draws on a mode of reasoning that. I will call the "logic of end-use analysis". I shall elaborate on this concept in the next section.

6 Concept of end-use rationality

The principal common denominator behind the three descriptions of AT provided by Darrow, Schumacher and Lovins is the notion that the techniques and resources used in any act of production must match, or be appropriate to, the end-use of that production. The appropriateness of a technology can be evaluated along technical, economic, social, cultural and ecological grounds. The concept of end-use rationality refers to the process of matching resources and techniques to the end-use taking into account the above criteria. End-use rationality has application in every   area of technology: food, nutrition, agriculture, manufacturing, health care, housing construction, transport and education. However, the first formal analysis of end-use logic arose in the area of energy policy and planning(Lovins 1977).

6.1 Laws of thermodynamics

The principle of end-use analysis derived its logic from the first and second laws of thermodynamics. The first law states that, like matter, energy is neither created nor destroyed, but any form of energy may be converted directly or indirectly to another form. Energy has not only quantity, but also quality. High-quality energy such as gasoline which is a available in a concentrated form has the ability to de work but low-quality energy such as waste heat which exists in a dispersed form does not. The second law of thermodynamics states that during the course of any activity high quality energy is changed into a more dispersed, less useful lower quality energy such as low-grade heat. Loosely, the quantity of unavailable energy (or low-grade heat) is referred to as the degree of entropy. In fact the second law is often called the entropy law. Because work uses high quality energy it always increases entropy in the environment From this we can derive the useful concept of the second law energy efficiency which is defined as :the ratio between the minimum amount of work required for a given task it the amount of work represented by the energy actually used to   accomplish   the task (Commoner 1977,p156).To illustrate this ratio: a pound of factory-produced fertilizer nitrogen requires about 19700 British Thermal Units of energy. But a pound of nitrogen (in a form useful

to the plant) can also be obtained by ploughing in a planting of a legume which would use about 2700 British Thermal Units per pound of nitrogen. On these grounds the conventional nitrogen fertilizer has a second law efficiency of about 14 per cent (=2700/19700). Since work always increases entropy in the environment the amount of unavailable energy) it is useful to inquire whether a desired level of work can be maintained while at the same time slowing down the rate at which entropy increases. Indeed, this would be possible if we carefully match the technology and kind of resources used to the task at hand, as was evident in the example of fertilizer nitrogen.

6.2 Energy end-use analysis

I shall illustrate the notion of matching sources to end-uses by using energy as an example. Consider two different ways of providing the energy needs of a region. In one approach the energy meets of homes and factories are supplied from a central electric grid, an energy-intensive option which. I shall call a " high entropy" path because it uses high levels of available energy (Rifkin 1980). The high entropy comes from three sources: the use of high quality fuels and material, energy losses in transmission, and the employment of electricity for a range of end-uses regardless of the actual temperature required for each use. Contrast this with a low energy strategy where we carefully match different types of energy needs to appropriate sources: irrigating with wind energy, ploughing with animal power, space heating with solar energy cooking with biogas or firewood, lighting with small-scale hydro electricity and so on (National Academy of Sciences 1976) I shall call the second, a "low entropy" option because it accomplishes the same quantity of work as the first, but uses a smaller amount of high-quality energy. Although the "low entropy" approach is quite sound in many respects, one of its principal drawbacks is the massive amounts of information needed to implement such a strategy. It needs data on : (a)energy demand and   type, (b) the supply of energy resources-types, amounts, variability and locations, and (c)the knowledge of technologies to match sources to the end-uses.

In the soft energy path studies done on the provinces of Canada Brooks and Casey 1979) the starting point was the construction of a detailed demand statement of end-uses by sectors-industrial, commercial, transportation and residential. Next, end-uses were classified by energy quality which was based on the form in which the energy was supplied: heat, liquid and electricity, with heat being broken down into three or more.

Table 1 An energy end-use table.

Energy Transport	Residential	Commercial	Industrial
Head (degrees centigrade) Below 100 101-315 316-1000 Over 100 Liquids Gas Electrical			

Temperature ranges. Together-with the consuming sector, a matrix was developed for each region showing the quantity of each type energy used in each sector (table 1). End-use tables can be constructed at any level of the geographic hierarchy, including province, district, town and village. Such end-use tables can be used for a variety of tasks that include the making of energy forecasts, search for conservation potential, the making of choices of new technology, and the matching of renewable sources of energy to specific types of end-uses.

6.3 Site-specificity of resources.

The potential yield of renewable energy, such as water, wind power and biogas, is very site-specific and variable in time. A stream contains two forms of energy: kinetic energy and potential energy. The kinetic energy groom the velocity of water in most streams is not great enough to be useful. What we try to harness is the potential energy between two sites of differing elevations. If a convenient site is not available on the stream itself, then it is usual to divert some of the upstream water, transport it along a channel or elevated conduit to another site, and then let it fall through a water wheel or turbine located at a lower elevation to produce power. The water then returns to the stream. The amount of power obtainable   from a stream is proportional to the rate at which the water flows and the vertical distance which the water drops (Leckie et al.1975).Since stream flow varies by month and season, the pattern of availability of water power is space and time specific in the physical geography of the region. On the other hand, the design of a waterwheel or turbine, the actual choice of a site and the utilization of power would depend on an array of attributes of the economic geography of the region: the distribution of settlements and the type and seasonal distribution of economic activities.

In the case of wind the theoretical maximum power that can be derived from a windmill can be calculated as follows:

$$P_{max} = 0.0031AV^3$$

Where P is power measured in watts, A is square feet of area swept by the windmill, and V in miles per hour is the velocity of the wind at the site (Leckie et al. 1975) Thus, the choice of a site for a windmill is a crucial decision. Since the

energy in the wind is proportional to the cube of velocity, small differences in wind speed mean large differences in wind power. Wind patterns are greatly affected by mountainous terrain. Even in flat regions of generally high wind speed small obstacles on the ground can slow the wine considerably. In the agricultural areas of poor countries one of the best uses of wind power is low-lift water pumping. Here the windmills operate at very low ranges of wind speed and need sites that are protected groom high winds.

A project to promote the adoption and diffusion of wind-powered lift irrigation in the Dry Zone region of Sri Lanka provides a good illustration of the concept that renewable resources have meaning only in the context of space and time coordinates of the physical and human geography or a region. The Dry Zone of Sri Lanka is that region which lies between the 25 " and 75" isoheyts of annual rainfall (figure 1).The main rainy season occurs between October BS Januarys during the period of the north-east Monsoon. The dry season occurs in the summer months from May to August .Large areas of the Dry Zone now have access to gravity-flow irrigation through the recently constructed Mahawelli water the principal option for highland cultivation is will-irrigation with pumps. Estimates based on census figures suggest that there is a potential marker in the

Pag 50 map, figure 1

Figure 1 The Dry Zone of Sri Lanka
Table 2 Lift-wind irrigation potential in the dry zone of Sri Lanka (After Greeley 1986,p 1414 and Spate et al. p 792).

Month	Rainfall (cm)	Assumed depth of water table (m)	Total pumping head(m)	Mean monthly wind speed (m/s)	Monthly output (m3)
January	15.24	2.0	3.5	2.1	764
February	5.16	2.0	4.5	2.2	865
Match	11.40	3.0	4.5	2.0	537
April	13.90	3.0	4.5	1.8	472
May	8.30	5.0	6.5	3.6	1500
June	5.60	5.0	6.5	4.8	2457
July	5.10	7.5	9.0	4.4	1892
August	7.60	7.5	9.0	4.4	1892
September	12.70	7.5	9.0	4.1	1565
October	20.30	7.5	9.0	2.6	677
November	22.80	1.0	2.5	1.6	509
December	17.80	1.0	2.5	2.0	995
Total Annual					14125

Dry Zone of about 300000 such irrigation pumps. Irrigation authorities in Sri Lanka believe that the highland farming in the Dry Zone area offers the best prospect for using wind energy in agriculture. The depth of the water table follows the pattern of rainfall, with its lowest levels occurring in the dries months of the year (table 2), but this pattern is inversely correlated to the variation in mean wind speed when the months requiring the most pump head coincide with the months of highest mean wind speed Greeley 1986) The site-specificity of resources as illustrated in the example puts a premium on geographical analysis. I shall explore the implications of this notion for GIS in the next section.

6.4 implications for GIS
before we move to an exploration of the implication of principles of end-use rationality to the tools of GIS, it is useful to extend the idea of entropy to cover matter as well as energy. Because matter in nature is recycled, but energy moves only one way, we tend to think that, unlike the degradation of energy, the degradation of matter is not a problem. However, Georgescu-Roegen (1971) has argued that available matter too can be become available. We can not recycle the rubber molecules dissipated from car tires nor the phosphorous molecules from fertilizer. A law is needed to proclaim for matter what the second law does for energy because unavailable matter can not be recycled. However, we must refrain from speaking of the entropy of matter as a measurable entity. Unlike energy, matter is very heterogeneous. Factors that dissipated matter vary greatly from one material to another so it cannot be subsumed under one general formula; nevertheless, the degradation of matter is real. I shall use the term entropy loosely to refer to both unavailable matter and energy.

The previous discussion of energy end-use also illustrated what may be called the principle of the entropy information trade –off, which states that minimizing the use of energy and material in production requires an opposite increase in the use of information (figure 2). (In the literature there is much confusion about the use of terms information and entropy which are used interchangeably. The confusion can be attributed to Shannon and Weaver (1964) who, upon noticing the resemblance of the mathematical formula for his signal theory measure of information to the measure of thermodynamic sense and the world information in its common everyday meaning of knowledge.) information unlike energy and matter does not follows the laws of thermodynamics. Information can be created and destroyed. According to the second law, energy when used is degraded to a lower, less concentrated form; no such tendency exists in information. Information can be lost in transmission, but this is a matter of noise in the channel, signal fidelity and problems in coding and decoding messages. Information exists at three levels: syntactic, semantic and pragmatic (Cherry 1961). Syntactic refer to signal, channels and the transmission of messages. Semantics refer to the meaning of messages. At the semantic level the sender and the receiver and their common pool of shared meaning are part of the act of communication. Pragmatics refers to effectiveness

Of information in attaining the objectives of the sender. The mathematical theory of information lies at the syntactic level of sign theory and is abstracted from the semantic and the pragmatic levels. In this paper I use the term information, not in its mathematical sense, but in the common everyday meaning of that term as it encompasses all three levels of communication. End-use rationality suggests that we can satisfy our end-use needs even as we slow down the rate of entropy in the environment. This is possible because, unlike energy and matter, information does not follow the dictates of laws of thermodynamics.

The main propositions that I wish to derive from this discussion of energy end-use analysis are:

1)the reduction of entropy trough the matching of resources to end-uses requires the use of high levels of planning information; and

2) since the matching of sources to end-uses is, for the most part, done locally, the concept of resources has meaning only in its regional context.

What are the implications of these propositions for GIS? First, a GIS has the negative attributes of increasing dependency, requiring foreign expertise and high levels of skill; but it also has the attribute of information technology which enable us to operationalize the concept of end-use rationality. Second, in end-use rationality the concept of resource becomes very places-specific. To elaborate: in this view the term resources has no meaning independent of the spatial location of needs, the location of sources to match end-uses local culture and indigenous knowledge. A GIS as a tool of spatial and regional analysis help us to implement the place-specific logic of end-use rationality. A GIS is very often viewed as a tool for mapping resources, where the meaning of the word resource is taken to be non-problematic and obvious. In end-use logic there is not generalized notion of a resource. Resources come into be and are discovered in the local area, contextually. A GIS, and its methodology of overlay, buffering and spatial modeling of physical and human data, is an indispensable tool for carrying out such an exercise. In summary, in the framework of end-use rationality a GIS is not a simple a tool for mapping resources that are self evident, but it is an instrument for discovering local resources contextually. Indeed, the full implementation of AT is not possible without access to a GIS because it is the knowledge of the region (and the ability of a GIS to enhance this knowledge) that makes AT a viable alternative to the current modes of development.

The concept of end-use rationality on low-entropy economic development has application beyond the field of energy policy. In agriculture energy and material inputs can be considerably reduced by substituting organic for industrial material, by adopting integrated pest management with biological and cultural controls and reducing the use of chemical biocides, adopting multi-crop farming systems integrated with animals that provide t reaction and fertilizer, and growing food locally to minimize inter-regional transport()Merrill1976,Wilken 1987, Horn, 1988).Simkilar end-use logic can be used in housing construction

by using local materials (Turner 1977), in health care by matching health resources to the regional health profiles, and by investigating the regional basis of the etiology of local diseases(Werner 1977,Good 1987).

7. Toward a more appropriate GIS

given the importance of GIS tools for the implementation of end-use rationality in AT we should seek ways to make the current technology of GIS more appropriate to conditions of the rural areas in the Third World.

One solution is to develop low-cost software for GIS. (For a listing of GIS and computer mapping software with prices and system characteristics see the Special report of GIS World on GIS technology '89.) there are two broad approaches to this problem:

1) use of a single, integrated system for file management and GIS;
2) use of a loosely-integrated system built around existing database and graphics packages.

Two low-cost integrated GIS packages are a) IDRISI, developed at Clark University by Ron Eastman, and b) MAP (Map Analysis Package), developed by Dana Tomlin at the Yale School of Forestry and Environmental Studies. They are both raster or grid-based systems designed to automate the process of cartographic overlay, with several user-oriented , drawing buffers around features, shading polygons and so on. MAP was designed for teaching purposes. IDRISI is a very viable low-cost alternative to ARC/INFO and it is being used in several planning offices. IDRISI is already installed in over 700 locations around the world (GIS World 1989).

7.1. CARP: Computer Assisted Regional Planning

in following paragraphs I shall describe briefly an effort to develop a low-cost system with elementary GIS applications by combining the excellent drawing editing features of CAD (Computer Aided Design) with the data management capabilities of DBM (Data Base Management). It is a part of a larger project called CARP (Computer Assisted Regional Planning), developed at the Pennsylvania State University to built a low-cost computer mapping and planning capability for use in the regional planning offices of the Third World by linking locally- available popular software. CARP performs elementary GIS functions by integrating a drawing editor (AutoCAD) and a database manager (dBASE) through on behalf on the Integrated Rural Development Programme (IRPD) offices of the Norwegian Agency for International Development.

The CARP system described here is not a new package. It is a conceptual scheme for linking a drawing editor and a database manager through a series of linker programs. The basic CARP system contains four components: 1) the digitizing of map data, 2) the construction of statistical maps with hatch patterns, 3) the writing of local text on computer maps, and 4) the computer analysis of map overlays for planning. Detailed descriptions of this work have appeared in earlier papers (Yapa 1988, 1989).

Part of the continuing work in CARP at Pennsylvania State University concerns the creation of a   CAD-based GIS. Previously the commands for such operations as joining line segments in to region boundaries , the instructions for producing hatch patterns on choropleth maps and the procedures for polygon overlay were done through linker programs written in QuickBASIC. Currently these instructions are being run by programs written in AutoLISP, a graphic programming language provided by AutoCAD. The commands for drawing choropleth maps, polygon overlay and buffering are run within the AutoCAD environment from the AutoCAd command mode. The map of moisture zones in Sri Lanka (figure 1) was produced by linker program written in AutoLISP and run for the AutoCAD command mode. The programs were developed by Li Wen yao (1990). Another line of research in CAD-based GIS currently under way is the search for adequate CAD programs that costs far less than AutoCAD.

The principal factor which shaped the thinking behind CARP is the nature of the thriving Asian computer cottage industry today. Between 1986 and1988 the author visited a large number of computer shops , both big and small, in the Asian cities of Bangkok, Manila, Singapore, Hong Kong, Jakarta and Colombo. Some of the smaller shops located in the back alleys of crowded main streets were simple family businesses run out of one or two rooms of private homes hurriedly converted to computer stores. Most computer shops served multiple functions. They sold, repaired and serviced hardware, primarily Asian-made PC-clones. They sold the newest versions of popular software, many openly admitting to the sale of pirated copies. The shops were well stocked with books on computers of popular software, some written in local languages as in Thailand. The stores also server as part-time schools where tutors provided instruction in both software and hardware to young men and women of high-school age. Because of high unemployment many high schools graduated attend computer classes in the hope of enhancing their chances of employment the private sector. CARP was designed to make advantage of this informal computer infrastructure that already exists in the cities and towns of Asia. We built the system around packages that are popular and widely used in the hope that local planners using CARP would seek help from the numerous local experts. Follow-up visits in 1988 to sites where CARP was originally installed provided evidence of how planners have taken advantage of local expertise. It was gratifying to see that independent of our own work at Pennsylvania State University, new programs and options have been added to CARP at the Asian Institute of Technology in Bangkok at the University of Hassanudin in Ujung pandang in the island of Sailawesi in Indonesia and in the integrated Rural Development Programme offices of the Hambantota and Moneragala districts of southern Sri Lanka (YAPA 1989). My viewed of CARP as AT is partly based on the fact that it was specifically designed to take advantage of the computer infrastructure that already exists in the countries of Asia.

In a short article written to the Computer Guardian in 1987 Batty described the thriving cottage industry in computer hardware and software in the golden Shopping Center in New Kowloon, Hong Kong. Copyrighted software such as dBASE, Lotus 1-2-3, and AutoCAD could be purchase there for a few dollars. Batted also reported that this industry is under thread of being shut down by

customs authorities. This raises a few interesting contradictory issues. On the one hand, we see in the Golden Shopping Center an obvious violation of proprietary rights of the software companies. On the other hand, there is the social reality that very few students.

Modeling   Regional
Methods   Geography

GIS

Indigenous
Knowledge
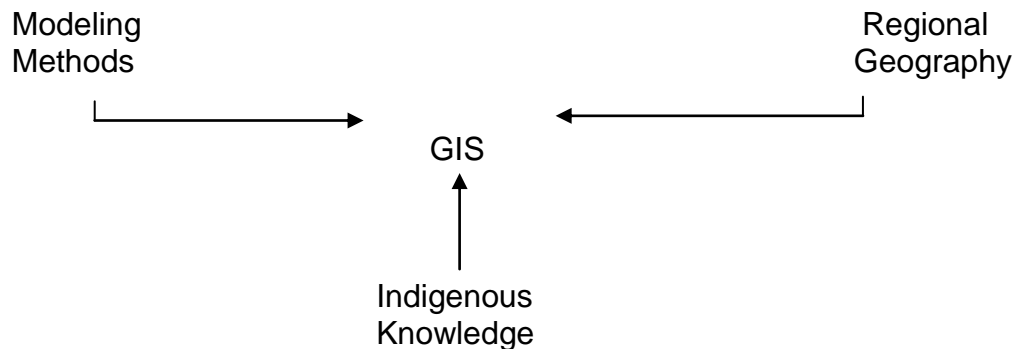
University professors or professionals working for small architectural and design firms in countries such as Sri Lanka, India and Philippines could afford to pay US$3000 for a piece of software. In Sri Lanka this sums amounts to twice the annual salary of a university teacher. Insistence on strict compliance of copy right laws in South and South-east Asia means only one thing- the inevitable non-use of the software. The resolution of this contradictory interests should be a concern of foreign assistance agencies. In this connection an imaginative model worth emulating is the production of low-cost Asian editions of American textbooks by Prentice-Hall of India which began a couple of decades ago.

7.2 local information systems
an important step in producing a GIS that is compatible with the philosophy of AT is the construction of a local information system that encompasses the GIS as a part of it (figure 3). In this connection five components of a local information system can be suggested:
1) a GIS with standard overlay and map query procedures;
2) a set of simple techniques for modeling such things as population growth and soil erosion;
3) a database of a local physical and human geography in maps, reports or digital form;
4) a mechanism for incorporating indigenous knowledge of the regional geography, local resources. Diseases, remedies and so on;
5) a system that encourages the participation of local people, in providing inputs to, using the outputs of, the local information system.

As far as is feasible, it is useful to conduct the operations of the information system in the local vernacular language. To facilitate this CARP has used an AutoCAD feature for drawing map text in local languages (figure 4). A successful example of people **********map*******************

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*participation in local information system with a computer component comes from the CARP project installed in the Moneragala district in Sri Lanka in 1987 (G. Batuwitage, personal communications, 1989). Among the many sub-projects in the district was a dairy co-operative scheme established to collect small quantities of milk from a number of farmers who maintain small herds of cattle to supplement their meagre incomes from food growing. The co-operative receives some help from the CARP system installed in the Moneragala district planning office. The program helps to keep detailed records of the entire dairy operation. The individual payments to farmers are based on a locally-derived formula related to quantity and fat content which is too cumbersome for daily calculation by hand. The farmers have access to the computer printouts of the accounts and they were taught to read the information relevant to their own accounts. This has eliminated the possibility of fraud and the cheating of the farmers, and has expedited the payment of money to the farmers by the co-operative. At the recent meeting of the milk co-operative society during which an animated discussion was conducted on the future of the liaison with the district planning office computer system, the most vocal supporters for continuing the system were the villagers themselves, some of whom have completed only a few years of grade school.

In Moneragala the CARP system is also used as a tool for the geographical monitoring of projects. This is a system whereby the financial and physical progress of project is tied to a location database permitting a map analysis and spatial monitoring of the projects (Yapa and Dilley 1989). In Moneragala the local planning office has made a conscious effort to incorporate the routine participation of village in the implementation of the information system. For example, the farmers regularly participated in meetings conducted by the Irrigation Department of the Rehabilitation of abandoned small reservoirs, some of it have been built several hundred years ago. The local farmers provide the engineers of the Department of irrigation with very useful information and advised on the selection of reservoirs to be repaired, on past water levels on cutting channels.

8.Conclusion

GIS bears a dual relationship to AT. On the one hand, they contradict the principles of AT because of their high cost and the need of high levels for expertise. On the other hand, they complement AT because the tools of At are useful for uncovering local resources.

AT is built on the logic of end-use analysis which means that the inputs and techniques of production must match the end-use so as to minimize the consumption of material and energy. Matching of sources to end-uses to minimize the use of material and energy requires an opposite increase in information. We can substitute information by material and energy because information does not follow the di¿?   Of the first and second law of thermodynamics. It is relationship that makes GIS an integral part of AT.

We can strive to reduce the negative impact of the contradictory aspects of GIS by employing several strategies: 1) the relaxation of proprietary rights over

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existing GIS software; 2) the development of public domain GIS; 3) the development of software that takes advantages of the existing software infrastructure in the Third World (this is the approach adopted by the CARP project); and 4) the establishment of strong local information systems where people's participation, indigenous knowledge and GIS function in mutually complementary ways.