7. Information technology and protected areas

Section 1

Introduction

“Truly effective biodiversity conservation demands inventory, evaluation, planning and management at scales ranging from the local and regional to national, continental and global” Nix et al. (2000).

Information Technology (IT) has the ability to store, analyse, and integrate data of different themes over different regions, and at different scales. The use of IT in protected area development and management will allow protected areas to be viewed as integrated parts of an overall landscape.

Previously, protected area managers combined printed maps of topography and land ownership with their knowledge of local climate, species distributions, topography, environmental law, and land use to define management zones and strategies. Today, all this data can be analysed in digital databases to provide for more efficient, accurate and informed decision-making.

Once protected areas were viewed and managed in isolation from surrounding landscapes and were often designated as non-development areas. Exploitative development sectors, such as mining, forestry, roads and energy, were viewed as a direct threat to the integrity of PAs. Now, it is understood that, unless PAs are planned and managed as an integral part of the wider development landscape, their benefits to socio-economic development will not be recognised and they will remain under siege.

The information needs of PA managers have also changed. IT can be a critical part of expressing PAs as part of a mosaic of land tenure and uses, where conservation and development are mutually reinforcing. The evolution of IT and its application to protected area development and management follows a progression from small-scale or limited theme data to regional issues using multiple data sources:

1. Hard-copy maps allow managers to clearly identify zoning in and around protected areas that reflects the varying intensities of conservation and use and the consequent management arrangements to be enforced. Maps display limited themes, however, and cover a specific region.
2. Databases of environmental policies (i.e., laws and regulations) or species statistics can be used to determine management regimes in different zones or to help identify biodiversity regions. Databases contain factual data but do not necessarily provide a spatial context for it.
3. The development and use of Geographic Information Systems (GIS) and Remote Sensing over the last decade has provided the ability to combine multiple data sources with land-use and species statistics. These tools provide a method of combining spatial data with attribute (descriptive) data that is often stored in databases, and allow multiple data themes to be viewed at both local and regional scales.
4. The increasing view of protected areas as networks and the need to analyse the relationship between PAs and surrounding development has given rise to the development of Decision Support Systems (DSS). A DSS (or intelligent GIS) allows multiple data sources to be combined and viewed at various scales. It also provides decision-making tools (derived from expert opinion) for multiple criteria analysis to meet conservation objectives.
5. The internet provides access to data from all over the world, and spatial data can increasingly be viewed at international scales: for example, to analyse the natural system connections across national boundaries, or for the basin of a river such as the Mekong, which flows through six countries.

The progression of information from simple maps and documents to Decision Support Systems (DSS) has allowed conservation areas to be viewed in a regional, integrated context. The rapid development of internet technology has allowed the expansion of data analysis from local to regional or global coverage. Protected areas can be treated as multiple-use zones that involve economic, conservation, and community values, instead of being considered in isolation from the surrounding landscape and economy.

Section 2

Using IT in protected area establishment and management

Hard-copy maps: developing protected areas

Hard-copy maps have been used for decades to display thematic data at various scales to promote bioregional analysis. The advantage of using maps is that they provide a spatial view of information and demonstrate the scale and extent of environmental features (Box 1).

Box 1. Using maps in PA management

Maps are frequently used by environmental managers to display information, such as the following:

- boundaries of protected areas;
- infrastructure such as roads, facilities and villages;
- topography such as elevation contours and rivers;
- proposed development sites; and
- political regions such as provinces and communes.

Using a map allows the spatial relationships between these various themes to be understood. Maps allow people to quickly perceive areas of conflict, such as whether a proposed development site is within a protected area.

By providing a visual method of expressing connectivity and area, maps provide a valuable context for detailed factual data. Protected area managers use maps to view several themes over a predefined area. By studying several maps together, managers can see relationships between regions and can begin to approach environmental management from a regional ecosystem perspective.

Achievement: Hard-copy maps provide a summary of information that is particularly valuable as an historical data source.

Maps are used frequently to support policy recommendations, as a reference for display purposes, and in publications. They need to be integrated with other data sources for decision-making, however.

Challenge: Hard-copy maps are generally limited to specific themes, such as topography or land use.

Integrating various themes needs to be done manually and it can be difficult to match data between maps, especially if they use different coordinate systems, are at a different scale, or use different classifications. This aspect of maps requires them to be updated and regenerated for specific applications.

Databases and modelling

Global concern about the declining quality of many PAs has led to efforts to determine more effective methods of developing and managing them. Planning needs to be integrated with the expert knowledge of environmental managers and outcomes of previous management strategies (Pressey et al. 2002b). Databases and mathematical formulae are used extensively, for example, in processing information relating to species distribution and area-wide planning. Databases and modelling are powerful mathematical tools that allow data to be stored and quickly referenced through a spreadsheet or table (Box 2). Developing a database allows information over different time periods to be stored, analysed, and referenced. Integration of data allows PAs to be understood as evolving natural systems, and can lead to improved PA selection and adaptive management. To gain a regional and spatial perspective, however, the data from databases and modelling need to be fed into GIS and DSS to provide an easily visualised framework.

Box 2. Using algorithms

The BIOCLIM program developed at the Australian National University is a data-modelling package that predicts flora and fauna distribution based on locations of known species. It is a valuable tool when species data is nonexistent or difficult to find. By identifying regions with the same environmental conditions (e.g. climate and topography) as known species locations, BIOCLIM can predict the presence of these species over extended areas. This modelling tool has been incorporated into the BioRap Toolbox DSS (Box 6) to produce predictive species distribution maps (Nix et al. 2000).

Pressey et al. (2002a) have developed reserve selection algorithms. These calculate the least cost of reserves (i.e. areas with minimal opportunity costs for alternate land use) while meeting a target level of representation of environmental features (e.g. species population or ecosystems). The algorithms can help determine the number of sites required to represent at least one occurrence of every feature (such as a species), or the number of sites required to represent five occurrences of each feature (e.g. flora and fauna species and water aspects).

This Interim Assessment Process utilises software that links a GIS to the natural resource software. The resulting maps show which part of the forest must be included as part of a future reserve system. The system allows conservation requirements to be met with minimum impact on the timber industry (RACAC 1996). Modelling can also be used to predict outcomes or as a management tool to select regions best suited for various land uses.

Databases and modelling tools are also used for the economic analysis of environmental data. Spreadsheets, databases and software packages such as SPSS are able to build economic models using regression analysis, linear and non-linear programming, and demand curve construction. These spreadsheets are valuable sources of the information used to assess the economic value of regions and are instrumental in assigning and managing protected areas.

Achievement: The quantitative methods of using advanced algorithms and modelling tools enable substitute and predictive data to be used where actual data is scarce.

These methods improve the range of information being used in protected area selection and management, and ultimately improve the protected area selection process.

Challenge: Modelling and algorithm development do not easily include expert knowledge or interpretation.

For verification, data and results need to be analysed with experts from a range of disciplines. Most models will need to be developed so they can be integrated into a GIS for decision-making analysis. Integration problems, include different file formats and lack of suitable GIS data on which to operate, also exist (Carver and Frysinger 1995). Many iterative modelling processes require powerful computers and are very time-consuming. This is a significant inhibiting factor in their widespread use for protected area planning and management (Brill et al. 1999).

Remote Sensing

Remote sensing refers to data collected by sensors that are removed from a data source. Sensors include cameras for aerial photography or satellites that record a range of data as digital signals. Passive remote sensors, such as satellites, operate much like cameras; the sensor receives and records spectral data that is reflected from the earth's surface. Active remote sensors, such as radar, send out signals to the earth's surface, record the waves that are reflected back and store them as a digital signature.

Remote sensing has the ability to collect high-resolution regional data and to be able to digitally change satellite images. Remote sensing can be a cost-effective method of acquiring data at regional scales, and it provides information about regions that are physically inaccessible. Relationships between large regions can be viewed, analysed, and used as a permanent record of environmental conditions (Terfai and Schrimpf 2000).

The Landsat satellite records visible, near-infrared, short-wave and thermal infrared (heat) signatures over an length of 183 kilometres. Landsat returns to the same region every 16 days; this means that data can be collected with regular frequency for temporal modelling (NASA 2002) and land change detection. Remote sensing can vastly improve the development and management of protected areas:

- it allows large regions to be viewed, providing a visual data source of connectivity between environmental features; and
- by processing satellite data applying algorithms, it allows features on the image, such as soil types, vegetation types, or roads and rivers, to be enhanced and used as the basis for ground mapping.

Remote sensing data can be used to study areas of human habitation — both past and present — and its relationship to protected area management. Remote sensing data has recently been used to study the extent of the Angkor Wat complex, a protected landscape in northern Cambodia (University of Sydney 2001). Angkor Wat covers an extensive area and the terrain can be treacherous due to landmines. This made remote sensing an urgent requirement in managing this World Heritage Site. Radar, Spot, and aerial photographs were used to identify existing features, such as water tanks and temples. Algorithms can be applied to the data to obtain the digital signal of known features; these can then be used to locate other areas in the region that were once inhabited and developed.

Technologies like remote sensing are powerful because they allow the viewing and analysis of data in treacherous or inaccessible areas. Stereoscopes, applied to remotely sensed data, allow a user to see a surface in three dimensions. This greatly improves the understanding of ecosystems in a region.

Achievement: Improved processing techniques have made some remote sensing data, such as radar, more useful for a broader range of applications.

Radar can penetrate cloud cover to gather earth surface information, while visible light sensors require clear skies. The advance of algorithms allows for more accurate surface classification, such as the Shallow Water Image Mapping (SWIM) algorithm that allows marine habitats to be mapped by removing the reflective effects of water and the atmosphere (Bierwirth et al. 1993).

Challenge: Although the price of remote sensing data has dropped significantly in the last few years, a Landsat image costs around US$600.

The computer systems and software required to store and process satellite imagery are also expensive. This often places remote sensing out of the price range of many managers in developing countries.

Geographic Information Systems (GIS)

The introduction of GIS in the early 1990s changed the way spatial data could be stored, viewed and analysed. GIS is able to integrate data of different themes and portray information over different regions and scales.

Through the use of GIS, a manager can easily do the following:

- see whether a proposed development clashes with area of high biodiversity;
- map out areas where different environmental policies apply;
- manage protected area facilities and draw them on a map of the region;
- store and manage information about visitor numbers and impacts; and
- map and manage cultural and heritage areas.

A GIS allows protected area managers to digitally update data, integrate various data sources according to individual needs, and dynamically produce customised information products, such as maps and graphs (Box 3). A digital elevation model, for example, can be combined with a dataset showing water resources to model water catchments in water resource planning.

Box 3. Landscape analysis in Nepal

A landscape analysis of the Makalu Barun National Park and Conservation Area of eastern Nepal derived a digital elevation model by using stereoscopes with SPOT satellite imagery and analysing this and other information in a GIS. This produced various information about the landscape, such as hydrological models, drainage networks and watershed boundaries for the management of natural resources (Zomer et al. 2001).

Cross-tabulation is a mathematical procedure that allows multiple variables to be compared with each other. It is especially useful when comparing satellite or GIS data over a period of time and analysing changes in features such as land-use or vegetation. The application of cross-tabulation to GIS datasets and remotely sensed imagery is a powerful tool in the temporal analysis of data. Often PA managers need to know how a landscape has changed over time, i.e. whether forest areas have decreased. The results of a cross-tabulation will produce a new image or map that shows the extent of change.

A fundamental component of spatial information analysis and product generation is in understanding the data and how it can be used. Metadata — information about the data — should be provided, along with spatial data to indicate how it should be used.

Metadata contains details such as the following:

- data custodian (who owns it and who to contact about the data);
- data accuracy (the accuracy of the attributes and the spatial location);
- extent (the region the data covers);
- data sources (who contributed to the data; this is especially important if data has been created by merging previous datasets);
- scale (resolution of the data before location, classification, and boundaries become less accurate); and
- lineage (what processing and generalisation has been performed on the data).

For example, if it is illegal to dump waste within ten km of a protected area, a manager will need to use a GIS to plot where the dump occurred, and overlay it with a protected area dataset. If the accuracy of the protected area dataset is only about ten km, then it will be difficult to say whether a dump site plotted to be five km outside the protected area border is actually illegal or not. This makes metadata an essential accompaniment to the distribution and use of spatial data (Box 4).

Box 4. The Environmental Data Directory, Australia

The Environmental Data Directory was developed by the Environmental Resources Information Network (ERIN) within Environment Australia. It is a metadata directory that allows users to search for environmental information by keyword, author, or region. It contains information about documents, digital datasets and other information that matches the user's request. This allows environmental managers across the world to locate environmental data (Environment Australia 2002a).

Achievement: The increase in quantity and quality of metadata means that GIS data can be used more effectively in decision-making analysis.

GIS programs are being developed for specific circumstances, which means that PA managers can use a simple GIS interface without years of training in spatial data management. The availability and quality of spatial data is continually increasing; this provides managers with an ever-improving information base to support their decision-making.

Challenge: GIS operates on the GIGO principle (Garbage In Garbage Out).

If the data in the GIS is of questionable quality, then the products derived from it will be even more inaccurate. For example, villages may be plotted in the wrong province, and data may be mismatched due to poor knowledge of projections. In developing countries, where resources are limited, may be difficult to obtain reliable attribute data and information on the properties of the datasets. In Nepal, for example, due to physical remoteness, lack of funds and personnel and/or political considerations, GIS data for protected areas were unreliable or at an inappropriate scale for resource management and ecological research (Zomer et al. 2001).

Decision support systems (DSS)

As environmental managers begin to deal with protected areas as networks rather than islands, decision support systems (DSS) are developing to allow multiple themes or criteria to be considered in regional planning. The criteria often used in the selection process include traditional land use, land ownership, climate, topography, geology, expert knowledge of environmental systems and socio-economic conditions. Through the integration of thematic data, ecosystems can be assessed over small and large-scale regions in a DSS, while incorporating expert knowledge for decision-making.

When making an environmental decision, there is an objective; i.e. what the decision-maker hopes to achieve. This may be to conserve biodiversity, or to select a community forest area in the region least prone to erosion. Within each scenario, there are factors and constraints that need to be considered. Factors include biodiversity, elevation, slope and soil type. A constraint is a more rigid consideration and is often something that is difficult to change, such as an area that is protected through law, or a lake. Each constraint and factor can be ranked on a scale of importance. A DSS will take GIS representations of the objectives, constraints and factors, and analyse these in an iterative process to produce a best outcome GIS map to meet the objectives. Many compromises need to be made when selecting best outcomes.

The maps produced by a DSS can be individually generated to show regions that best meet an objective. The DSS processing routine can also be run iteratively to see which regions best meet other objectives. Sets of maps can be generated for each objective, demonstrating potential outcomes for each decision-making option.

A DSS aims to integrate expert knowledge and the priorities of all stakeholders with environmental data. A DSS can encompass multiple objectives and can produce management maps that meet each objective (Box 5).

Box 5. Using decision support systems

Carver and Frysinger (1995) use the example of a chemical company that wishes to locate a factory as close to a river as possible to incur minimal discharge costs, while the city council, for public health reasons, wants the factory to have minimal impacts on waterways. Differing objectives like these often cause conflict in the decision-making process. In this instance a DSS can be used to generate a map of distances from waterways and cities. Using criteria such as legislative constraints (i.e. not building factories within 500 m of a waterway, or within two km of a city centre), a DSS can select and print a map showing which sites are suitable for the factory.

Achievement: DSS allows managers to easily analyse objectives, factors and constraints through a computer interface (Box 6).

Data can be scaled and each step in the analysis process can be further broken down and analysed. Data models can be continually adapted to changing conditions (Terfai and Schrimpf 2000). Digital data availability and accuracy is increasing, and algorithms are continually being refined.

Box 6. The BioRap Toolbox

The BioRap Toolbox is a decision support system that allows for the rapid selection of high-priority areas for conservation and sustainable management of natural resources. Several modules within the system are required to analyse different data.

The ANUSPLIN module can be used to generate climate surfaces, the ANUDEM module generates digital elevation models, the ANUCLIM module generates bioclimate data and the PATN module can determine environmental domains using abiotic data. Priority areas are set in the TARGET module. This module determines areas that represent biodiversity features and minimise the required area, and balances these outcomes against opportunity costs and other constraints.

The DSS is founded on two fundamental databases. The environmental database integrates a digital elevation model, monthly mean climate surfaces (precipitation and temperature) and lithology. The biological database was developed using expert knowledge of ecologists and taxonomists and existing specimen data. Where biological data is limited, species distribution maps can be generated using biotic and climatic data in the ANUCLIM module. These species distribution models, along with environmental domain and vegetation data, can be used as surrogates where biotic data is lacking.

Resource Mapping Units (determined from aerial photography) and Forestry Mapping Units (containing information such as forest and timber concession areas, protected areas, and vegetation type) are integrated to determine Biodiversity Priority Areas. Costs and constraints are factored into the iterative procedure of determining these areas. The toolbox factored in opportunity costs such as timber volume and agricultural potential, and existing constraints such as protected areas, population density and land-use intensity.

The TARGET software then runs an iterative procedure to meet the objectives, taking constraints and factors into account. The result is a set of biodiversity priority areas that meet biodiversity targets while minimising loss of opportunity costs and avoiding regions such as those with high population density or high land-use intensity (Nix et al. 2000).

Challenge: Getting decision makers to arrive at objective priorities can be difficult.

Arriving at a consensus when priorities conflict and the stakes are high is a demanding negotiation process. Collecting and collating the large amounts of data required for a DSS can be time-consuming and expensive. Data needs to be compatible and of comparative accuracy to produce high-quality outputs.

The internet

The massive expansion of the internet over the last ten years has allowed information to be shared between organisations, regions, countries and continents. The internet provides access to electronic data that includes publications, online databases, and, more recently, GIS and DSS databases. Internet access has wide ranging implications for protected area development and management through increased accessibility of global software and data.

Several internet-based products that provide increased access to environmental information have been developed to improve environmental decision making. (Box 7).

Box 7. The Australian Spatial Data Directory

The Australian Spatial Data Directory (ASDD) is a national metadata framework supported by organisations and governments under the auspices of the Australian and New Zealand Spatial Information Council (ANZLIC). The ASDD links government and commercial sites in each state/territory with federal government departments who are custodians of spatial data. The Environmental Data Directory (Box 4) is the Australian Department of Environment and Heritage component of the ASDD. It allows users managers across the world to find and locate environmental data (Australian Land Information Group 1999).

As internet GIS technology has improved, so has the quality and availability of internet-based GIS systems. In Australia, with its widely dispersed population, it is important to make data available over great distances (Box 8). This makes the internet a useful tool in providing information to the public.

Box 8. The Australian Natural Resources Atlas

The Australian Natural Resources Atlas was developed through the National Land and Water Resources Audit. It provides access to a range of information to support natural resource management. Data available through the atlas includes topics such as agriculture, coastal information, land resources, people, management of natural resources, rangelands, water resources, vegetation and biodiversity. The atlas produces reports through the internet that include text, pictures, tables, graphs, and GIS maps covering any region and at various scales (Environment Australia 2002c).

Achievement: The internet's most significant achievement has been making information available to decision-makers throughout the world.

GIS data can be downloaded from directories; metadata improves the way this data is used in the decision-making process. The internet increases the range of information to which decision makers have access. It also has the potential to improve the quality and methods of environmental assessment and protected area management from local to global scales.

The development of the Open GIS Consortium (OGC) is leading the way for global standards to be developed for spatial data. OGC Web Services will allow spatial data systems across the world to communicate with each other through the internet without the need for propriety software (Open GIS Consortium 2002).

Challenge: Variable speed and cost are the major drawbacks of using the internet.

These are of considerable importance in developing countries where computer networks and internet systems are unreliable and often unaffordable. Many organisations in developing countries do not have access to the internet. Detailed metadata remains a challenge as data organisations begin to document their data stores. The lack of metadata and international data standards means that data may be used inappropriately.

Spatial planning: future directions

Spatial planning involves analysing the locational relationships between environmental factors. Decision support systems are increasingly being used in spatial planning to select high-priority areas for conservation and development. Work by Pressey et al. (2002b) uses algorithms and DSS modelling to select areas that meet conservation targets. The BioRap toolbox described in Box 6 incorporates a range of environmental datasets to analyse biodiversity regions and target regions for protected areas. Remote sensing can be used to view land cover and monitor changes over large regions. Using a GIS to view thematic datasets can help determine land-use zoning and set priorities for development and conservation.

All these technologies focus on particular aspects of conservation or development. These aspects include geology, vegetation, land-use, population, topography and infrastructure. For optimal spatial planning, environmental aspects of PA development and management need to be incorporated with other important factors such as cultural values, legal frameworks, environmental economics, poverty and event prediction. When all these factors are analysed, spatial planning for protected areas will begin to look at networks.

Environmental economics and GIS

PAs are beginning to be seen as contributors to the economy by providing a range of services and products. Economics can be expressed spatially: natural resources have a location, markets have a location, resource users fall within administrative boundaries, and trading regulations apply to specific political regions. If environmental economics can be incorporated into spatial planning, the conservation and exploitative values of PAs can be assessed in the context of an integrated landscape.

Cropper et al. (2001) used statistics and GIS to determine the relative economic benefits of deforestation and forest conservation in protected areas in Thailand. The analysis modelled the relationship between PAs, roads, and regions of deforestation. A GIS was used to store data on land use, roads, slope, elevation, soil, urban areas and population density. Regression analysis determined whether clearing forests was more economically viable than preserving them; this analysis was integrated with spatial data, such as proximity to roads. Using these data, the authors tested whether clearing forested land would continue if the profits from clearing had exceeded the profits from leaving land forested. This model was also used to propose where PAs should be located to reduce potential deforestation.

Brainard et al. (1993) compared the economic benefits in Wales of agricultural land use with those of conservation through forestry. Under a government scheme, farmers can convert their land to woodlands. If economic benefits, such as tourism, can be proven to farmers, it would encourage them to make the transition. GIS datasets of population density and visitor numbers from each time zone were used to predicted the number of visitors. Applying this function to GIS datasets of travel time and distance, a cost of visitors to these forests was determined. The result is a map of the predicted economic benefits of tourism for recreational forestry in Wales.

Incorporating cultural values with GIS

Without the support of local communities, land-use strategies — including conservation through protected areas — are difficult to implement and manage. Cultural values must be incorporated in natural resource planning in order for communities to participate and have a sense of responsibility for resources. PAs are sometimes imposed on existing communities that once had free access to resources, making them opposed to PAs and the restrictions that are subsequently enforced. The inclusion and mapping of cultural values is becoming increasingly important if the sustainable use of protected area resources is to be maintained. By including a GIS dataset of cultural values, PA managers can locate areas of cultural significance and include them in planning decisions. GIS and DDS do not easily allow cultural values to be included, however. But by respecting and incorporating community values into spatial planning, PA management plans will receive more support from local communities.

Harmsworth (1998) has used GIS to map the cultural values of tribal areas in New Zealand. A database was developed to record Mäori cultural values, including details on sacred sites, indigenous place names, archaeological sites, traditional flora, (used for weaving, medicines etc.) and fauna (fish, insects) as well as their locations. Data was assigned to different political levels, from national to tribal. The information records the original source, such as a person, book, or map and is spatially represented in the form of GIS layers. This database and GIS system take into account intellectual property rights, sensitivity, confidentiality and links to other non-computerised knowledge-based systems.

Law mapping: responsibility and authority

The majority of legal databases do not have a spatial component. Most laws apply to specific regions, such as countries or states. Attributing legal databases with a spatial location allows PA managers to record law violations, such as illegal logging or hunting within protected areas.

The *Environment Protection and Biodiversity Conservation (EPBC) Act* in Australia requires that all actions that have, or are likely to have, an impact on a matter of national environmental significance will need Commonwealth approval. This means that all development projects need to be assessed for their potential impact on protected areas such as World Heritage areas, Ramsar wetland sites, and threatened habitats and species. Since all proposed developments have a location, they can be analysed within a GIS to see if they will cause the *EPBC Act* to come into effect. To assist in implementation, Environment Australia developed an internet-based interactive map (GIS) and interview system. The software allows users to digitally draw their proposed development site on a map of Australia. The GIS then generates a buffer around the area and searches for environmental data about World Heritage sites, Ramsar wetlands, and other protected areas. The applicant can use the GIS and species databases in Environment Australia to find which nationally threatened or migratory species occur in the proposed development region and what development projects have been already been proposed there (Environment Australia 2002b). This process allows users to easily determine whether their proposed development will require government approval under the *EPBC Act*.

Probability mapping

GIS is particularly powerful in predicting natural events. This can be done by storing and analysing existing geographical data to develop data models. By changing variables in these systems, patterns can be determined and future events can be predicted.

When developing management plans for PAs, it may be useful to know which areas of the PA are prone to natural disasters, such as flooding or fire. For example, rainfall, runoff, soil type, and topographic datasets can be used within a GIS to predict flooding. Physical characteristics of the landscape such as porosity, slope and vegetation can be stored in a GIS and used to determine how much rain will be lost as runoff. This can be integrated with hydrologic models to determine how deep the water will be in certain regions. This information can be combined with topographic data to determine which areas will flood, and which infrastructure will be most affected.

The International Rice Institute (2000) undertook an analysis of rice-aquaculture systems in the Mekong Delta. The results were used to determine how well the system would work in Bangladesh. A productive rice-aquaculture system in Vietnam is practised on deep-flooded lands with moderate to severe salinity levels. A productivity model was developed from a database on the effects of salinity on rice. A GIS was used to store data from Bangladesh, including: economic data, soil conditions, history of protection from salinity intrusion, and administrative districts. The productivity model was applied to determine the productivity of a rice-shrimp cropping system for Bangladesh.

Similar modelling can provide information about the contribution of PAs to productivity in agricultural landscapes. Predictive modelling such as this can also be used when developing multiple land-use strategies for PAs, where it is important to use resources while adhering to conservation guidelines.

Poverty mapping

These maps identify regions with the highest levels of poverty, which need to be the target of resources and investments (World Bank 2002). They can also contribute to more effective protected area establishment and management, which will bring sustainable livelihood benefits to disadvantaged communities. In South East Asia, most PAs are located in regions with the highest poverty. This fact is vital in PA planning: these impoverished areas will depend heavily on natural resources within the PA.

Most poverty maps are derived by aggregating data about the following aspects:

- economic (consumption and income);

- social (nutrition, sanitation, health, education);
- access to opportunities (land, credit, decision-making);
- natural resource wealth (agricultural productivity, food security); and
- geographic infrastructure (access to markets, income from surplus natural resources).

Geographical targeting increases aid efficiency by targeting poor areas. Bigman and Fofak (2000) state that GIS is useful in that it can aggregate survey data according to geographic areas that are different from the administrative regions from which data are selected.

The World Food Program's Vulnerability Analysis Mapping unit (VAM) works in collaboration with the Food and Agriculture Organisation's (FAO) Global Information Early Warning System, USAID's Famine Early Warning System and non-government organisations. GIS is used to store satellite imagery, data on poverty, rainfall and crops, and other information. Analysis is performed to calculate food insecurity and determine where food aid should be targeted (World Food Program 2002).

The FAO Global Information and Early Warning System on Food and Agriculture contains databases on food supply and demand as well as economic, political and agricultural information. By analysing past trends and current conditions, the system can predict where drought or flooding is likely to occur and where food aid is most likely to be needed (Food and Agriculture Organisation 2002). The FAO has also developed an internet GIS system that allows users to look at satellite images and build customised maps.

Although these applications deal specifically with emergency relief situations, they point the way to managing protected areas as productive units within their socio-economic landscapes and recognising them as natural resource "safety nets" for poor communities.

Conclusion

Planning for economically and environmentally sustainable development needs to make use of integrated spatial planning that incorporates protection and development factors over broad regions.

Databases, GIS, DSS, and the internet allow socio-economic and conservation factors to be viewed easily as maps. Applying algorithms to data allows high-priority areas to be selected for conservation and development. By integrating environmental economics, cultural values, law boundaries, and socio-economic status for regions, multiple land-use strategies can be defined that include protected areas and their natural functions as critical ingredients in achieving development goals.

Even as the technology to store and analyse data rapidly improves, however, many organisations struggle to obtain and manage data. Without accurate datasets, data documentation (metadata), and skilled staff, decision-makers can become too dependent on GIS and DSS maps. Solid data management capacities need to be developed so that the use of incomplete or flawed principle does not lead to unwise economic and natural resource management decision making that excludes protected area benefits. When properly managed, IT is a powerful tool for planning and managing protected areas as part of socio-economic and natural resource landscapes.

Section 3

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