Introduction - Introduction to GIS

Coastal zones are complex places. They are physically dynamic, subject to multiple resource demands, carry risk for risk for coastal populations, and are ecologically very important. The coasts of Central and Eastern Europe face particular challenges related to the management of spatial resources at the coast, including population growth, increased tourism pressure, economic restructuring, and a legacy of pollution. The complexity of coastal zones makes them inherently difficult to manage, however, good quality and timely information can assist better decisions. This places a particular
importance on managing information for those tasked with making important
decisions about coastal areas.

Geographic Information Systems (GIS) are decision-support systems, which can be
used in the management of spatial resources. GIS reflect many of the underlying
principles of ICM; GIS is interdisciplinary, holistic and facilitates integration of data
and interests. GIS are increasingly seen as a key tool in the preparation, delivery and
monitoring of ICM programmes. The use of GIS within ICM programmes offers several
benefits, in particular:

- a convenient technology to store and manage large sets of spatial data
- an effective tool to identify spatial relationships and patterns
- a recognised methodology to assist in decision-making
- a mechanism for the production of high quality maps

More generally, GIS can facilitate improved use of information to inform management
decisions. For example, in a coastal management programme in the Strymonikos and
Ierissos Gulfs, Greece, it was commented that "good knowledge of the environmental,
social, economic and administrative features of the area to be managed is the first
essential step in planning integrated management and sustainable development" (Go
to the Strymonikos practice example)

Specific uses for GIS in ICM programmes might include:

- conflict mapping
- development planning
- hazard management
- Environmental Impact Assessment
- public participation

In fact, a GIS can be used to assist in any situation in which spatial data is important.

However, GIS also have inherent problems, which need to be addressed by GIS users
to avoid misleading analysis. Typical problems might include:

- Collecting accurate spatial data
- Deciding on the format of data
- Entering the data into the GIS
- Maintaining data quality
- Integrating a GIS into a decision-making process

GIS therefore have much to offer to the coastal manager, but in order for GIS output to
be useful, the user needs to have an understanding of how GIS works and how the
strengths of GIS can be maximised and the weaknesses minimised for any given study.

Introduction - Learning outcomes

After successfully completing this module, you will be able to;

- describe the functional basis of a GIS
- appreciate the potential uses of GIS in ICM
- consider the benefits and shortcomings of using GIS for ICM
- outline the key data quality issues involved in using GIS
- develop a strategy to implement an effective GIS

In practical terms, by the end of this module, you should know enough about GIS to know what it is, how it can help you, potential problems to avoid, and how to go about setting up your own GIS. Before going further, it should be noted that all GIS vary in their design, operation and configuration. This module does not provide training to a particular type of GIS, instead it seeks to give an overview of the practicalities of using GIS for ICM.

Concepts - Definition

QUESTION TO USER

Use the space below to write down how you would define GIS:
Concepts - Background

GIS has developed rapidly over the last 30 years to become one of the most important tools at the coastal managers disposal. Key innovations in a variety of disciplines have facilitated the development of GIS, including computer science, database systems, image processing, and remote sensing.

At first, GIS were developed to address specific problems, such as the Canada Geographic Information System developed to address large-scale land use planning concerns. These systems were unique, expensive, difficult to use and allowed only limited data transfer. As the GIS market expanded throughout the 1980s and 1990s, commercial companies developed generic systems which can be bought cheaply, are easy to use, and allow the incorporation of data from a wide variety of sources (for example, see www.mapinfo.com, www.esri.com, www.idrisi.clarku.edu). A summary of the history of GIS can be found at the GIS Timeline.

In parallel with the development of GIS, has been the development of Remote Sensing technology, most notably aerial photography and satellite imagery. Remotely sensed data is now available relatively cheaply and easily via the internet and is a key source of data for inclusion in GIS (for example, see www.coastbase.org, www.terraserver.com).

Emergence of GIS for ICM
Bartlett & Wright (1999) stated that coastal and marine GIS face "the challenges of representing a highly dynamic, multi-dimensional, fuzzy bounded environment" (p. 309). Despite these challenges, GIS use in the coastal zone is set to increase, for several reasons:

- need for data to make decisions
- cost of research in marine areas very expensive
- commercialisation of GIS (especially in hydrography and oceanography).

Perhaps even more important in the emergence of the use of GIS in ICM has been the increased incidence of collaborative coastal/marine management in which the need for good quality information has proved crucial. This is demonstrated in the Epirus region of Greece on the Ionian Sea, follow the link to the full example.

Currently, the greatest constraints to the use of GIS for ICM are:

- data quality
- how data can be updated

......not computing power

**Concepts - General Concepts**

**The GIS decision loop**

It is important to recognise that GIS are only one component of a decision-making loop. The loop has 3 main components:

1. **Reality**

This is the situation that requires improved management. It may be an estuary, beach or other coastal unit. A simplified version of reality can be established through the collection of data. The data needs to have a spatial and attribute components.
Together, these components allow the GIS user to determine ‘what’ happens ‘where’. It is important that the data collected accurately reflects reality. Deciding upon data sources and ensuring the collected is of high quality are therefore both very important.

2. GIS

Once the data has been collected, it is entered into the GIS. The GIS therefore contains data layers, which together represent a model of reality. The layers can be overlaid or combined to identify geographic patterns and relationships. Furthermore, because the data is stored in a database, the data can also be used for statistical and other numeric analysis.

There are several methods of data input, each of which can affect data quality and data format. Data can be stored in the GIS database in raster or vector format. The format of data can also influence data quality.

**Data input** methods include:

- Keyboard entry
- Manual digitising
- Automatic digitising
- Electronic transfer
- Scanning

**Spatial data** is data that provides the location of an entity. The location should be given in accordance to recognised co-ordinate system, such as longitude and latitude. A dataset with geographic co-ordinates is described as being georeferenced.

**Attribute data** is data that describes the characteristics of a given location. The characteristics can be qualitative or quantitative, but should provide a description of an entity. Most often, attribute datasets are provided in a thematic layer. For example, a layer showing water quality, flood risk, or planning areas.

**Data Sources**

Data for inclusion in a GIS can be derived from a number of sources, as long as the data can be georeferenced. Data sources include:

- Existing maps
- Aerial photographs
- Satellite images
- Written reports
- Statistical surveys

Because GIS can accept data from a wide variety of sources, it is often referred to as a ‘data funnel’.
**Raster**

Raster format data represents reality as a grid, rather like a chessboard. Each square (or raster cell) covers a discrete geographic area and has one attribute associated with it. The raster cell is the smallest geographic unit that can be represented within a raster GIS, so it is known as the 'minimum mapping unit'. The smaller the minimum mapping unit, the higher the resolution of the dataset and the greater the amount of detail that can be represented.

Visually, shapes or geographic patterns are represented as by combinations of raster cells. This means that complex shapes (such as an administrative boundary) or linear features (such as coastlines) can look quite blocky and unnatural. Most remotely sensed data is collected in raster format, which means the data does not need to be converted prior to use in a raster GIS.

**Vector**

Vector format data visually represents reality through combinations of points and lines. These can also be joined to form polygons. This means that it is much easier to represent complex shapes or linear features in vector format, as the required detail can be inserted. Most map output from GIS is produced in vector format. Remotely sensed data will require conversion before it can be used in a vector GIS.

The following two diagrams show raster and vector representations of the same coastal area. Note how the raster representation has a block-like appearance, whilst the vector representation is made up of points, lines and polygons.

**Raster representation**

```
R  L  L  L  L  L  L  R
L  R  L  L  L  L  R  R
L  L  R  R  R  L  R  L
L  L  H  L  L  R  L  H
B  B  B  B  B  B  B  B
S  C  C  C  C  C  S  S
S  C  C  C  C  C  S  S
S  S  S  S  S  S  S  S
```

*R = Road, L = Land, H = House, B = Beach,*

**Vector representation**

![Vector representation diagram]
Comparison of raster and vector formats

### INSTRUCTION TO THE USER

Complete the table below to consider some of the advantages and disadvantages of raster and vector format

<table>
<thead>
<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raster</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vector</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Decision

The output from the GIS can then be used to support a management decision. The mechanism through which the GIS output influences the management decision will vary according to the particular institutional context, but it is important to remember that the GIS only provides data in a convenient way to help make decisions. GIS DO
NOT make decisions.

The decision closes the decision loop as the decision influences reality. The role of the GIS however, continues, in relation to the monitoring change and the refinement of management action.

In order to appreciate more fully the potential for the use of GIS, follow the link below to a web-hosted GIS. The site is focused on the United Kingdom and enables the user to manipulate numerous coastal data layers. It is possible to add and remove layers from the map and zoom in and out, as with any GIS. This example shows very well how geographic patterns can be identified provided the data is readily available.

www.ukcoastmap.com

Practice - Implementation

The implementation of a GIS is a complex task and should not be underestimated, however, the benefits to be gained are significant. They include:

- Clearer mapping
- Establish geographic baseline datasets
- Easier manipulation of data
- More convenient data storage
- Ability to establish relationships between geographic variables
- Enhanced capacity for decision-making
- Enhanced ability to communicate with stakeholders

There are also a number of contraints, or potential problems, which can undermine the quality of any GIS analysis. These include:

- Quality of the data
- Availability of data
- Cost of hardware and software
- Cost of data
- Level of training of the user

This section provides seeks to help you consider how to maximise the benefits
through minimising the constraints.

The implementation of a GIS to assist with decision-making needs to be undertaken carefully in order to ensure that the maximum data quality is maintained throughout the decision loop. The following issues are important to consider:

- Complexity of the reality being mapped
- Organisational considerations including personnel and training needs
- Data quality
- Cost
- Source data
- Time Specific considerations related to the coastal environment

**Specific considerations related to GIS for ICM:**

Bowers (1992) identifies 4 ‘facts of life’ with respect to information for coastal decision-making:

1. no analysis for ICM can include all data and/or analyse all alternatives;
2. there are physical and psychological limits to human capacity as a decision-maker (bounded rationality) and too much information obscures the trade-offs involved;
3. only a limited amount of data related to any given analysis can be presented at any one time, due to: · complexities of coastal ecosystems
   - complexities of coastal decision-making
   - the multiple use nature of the coast
4. the format used to present results will affect:
   - the amount of data that can be presented
   - the extent to which the data can be understood

**GIS project management**

In order to increase the probability of successfully implementing GIS for a specific project, a strategy should be developed which takes account of all elements of the decision loop in order that data quality is maintained and decision quality optimised.

A typical GIS project management progression might be as follows:

1. **Determine the aim of the study**
Define the required outcome of the project must be stated clearly eg. to identify an area suitable for the deep sea disposal of offshore structures.

2. Identify data needs

- construct model of reality
- Need appropriate data to make an informed and strategic decision
- Define parameters

3. Prepare a plan of GIS use (sometimes called a Cartographic Model)

- This is a flow diagram charting the datasets to be used and the analytical techniques to be applied. This is as important for quality assurance as it provides a record of what analysis was undertaken
- Prepare a GIS project log

4. Assemble the required data

- This may include a combination of:
  - new data
  - archive data

But important considerations are

- the quality of the data – is it appropriate to the study?
- data management – management is needed to maintain data quality

- Constraints:
  - time
  - money
  - context of study

5. Enter the data into the GIS

- choose data entry method
- data sensitivity analysis – consider impact of data quality in final result

6. Interrogate the GIS

Checklist of details to be included in a GIS project log (adapted from Heywood, et al., 1998):

1. GIS project title
2. Aim and scope of the project
3. Geographical area concerned
   - Dimensions of the area concerned
   - Resolution required
4. Users of the GIS
   - Who are they?
   - What kind of knowledge do they have?
5. List of data layers required
6. Analysis requirements
   - List of functions required
   - Flowchart of analysis (cartographic model)
7. Choice of GIS software
   - Principal requirements
   - PC/workstation/network
   - Risks
8. Choice of hardware
   - PCs/workstations
   - Networking
   - Peripherals
9. Resources and costs
7. Make decision

- system identifies potential sites
- decision based on other factors also
- value judgments
- role of GIS to aid decision making

In summary, it is important that data quality is appropriate to the level of the decision being made. If data quality is too low, the decision will be sub-optimal. At each stage in a GIS project there is scope to weaken data quality, therefore the project must be carefully managed to maintain appropriate data quality. In coastal zones, because the elements being mapped may be more complex, the importance of data quality is likely to be enhanced.

Software and Hardware required

Finally, it is important to consider the practicalities of setting up a GIS. Today, GIS software packages can be bought 'off the shelf'. These are empty of data, but otherwise ready to use. Once you have entered the data you require, they can begin to help you make better decisions. To run modern GIS packages requires relatively little specialist equipment to gain immediate benefit from its use. The major expense and most important requirement is a good standard personal computer. The two main considerations to make with regard to the specification of the computer are memory capacity and processing speed. The larger the memory, the more data it can hold, and shorter processing times reduce analysis time. A good quality printer can provide professional output.

Essential:

- personal computer
- printer
- Back up data storage system

May be required:

- Scanner
- Digitizer
- Large paper size printer
The cost of setting up GIS will vary according to the hardware needed, software chosen, and expense of data collection and entry. It is therefore very difficult to estimate a cost. General advice is that the larger the project (large numbers of datasets, complex analysis, etc), the higher the specification of equipment that will be required. For smaller scale projects, a standard desktop PC, printer and scanner will be fine. GIS can therefore offer a relatively cost efficient way of improving decision-making. It is important to note that the cost of establishing GIS is front loaded, with investment required at the outset. However, once the initial expenses have been met, expenditure is relatively small.

Practice - Exercise

You are tasked with the production of a coastal management plan for a small estuary on the Baltic Sea. The estuary has important areas for nature conservation, but is also has a small port and is therefore used by commercial shipping. The estuary is also used for recreational sailing and swimming. In order to inform management decisions, you decide to use GIS. The ultimate aim of the management plan is to reduce conflict between the users and the natural environment and provide a basis for future sustainable use of the estuary.

Work through the following questions to help you think about how GIS could be used.

QUESTION 1

What information do you need in order to help produce the management plan?
QUESTION 2
Consider how to identify areas of use-use and use-environment conflict. How would you gain this data?

QUESTION 3
You should now have a brief project plan to use GIS to assist with the management of a small estuary. In practice, this plan would need to be more detailed and worked through more carefully. In particular, the implications of using GIS should be considered in relation to the cost of system implementation, data availability and cost, any training requirements, additional staffing and of changes to working patterns that the use of GIS may require.

**Practice - Evaluation**

This exercise sought to illustrate the challenges of maintaining maximum data quality throughout the GIS decision loop. There were several stages in which data quality could have been compromised:

*Original data collection.* Data from members of the user groups may not be reliable. Each user may perceive 'conflict' differently and so provide inconsistent data. This is an important issue, as once the data is collected, it virtually impossible to improve its quality.
Data input to the GIS. There are a variety of methods of inputting the data to the GIS. Each has inherent advantages and disadvantages and the appropriate method must be identified in order to minimise the risk of compromising data quality.

Data analysis. Any manipulation of the data within the GIS may negatively influence data quality. Particular risks include changing map projections, modifying the scale of data and overlaying several data layers.

Presentation of data. The style of data output can influence the perceived importance of the results. For example, if the areas of conflict were coloured red, they may be treated differently than if the areas of conflict were coloured brown or green. It is important to recognise that the way in which GIS data is presented can influence the outcome of the decision to be made.

This exercise is typical of the use of GIS in coastal management. Data is of uncertain quality and the GIS output is required to make specific management decisions. The role of GIS is to help make better decisions than would otherwise be the case, therefore the careful management of data and data quality is potentially very important. There is a clear connection in the GIS decision loop between all components of the loop, if either data collection or the use of the GIS are in any way sub-optimal, then it is likely that the final decision will also be sub-optimal. This is why GIS is so important to the implementation of so many coastal management programmes.

If you followed the exercise through to question 3, you will also have put together a brief GIS plan to consider how GIS can be used to tackle a problem of importance to you. You could use this plan to research data availability and general resource considerations for the full implementation of a GIS. Completing this task for an area known to you should also have demonstrated the degree of preparation and forethought required to undertake a GIS project.

Practice - Practice Examples

The following examples of the need for, or the use of, GIS in coastal management are intended to illustrate the challenges and benefits of using GIS, and also how GIS can be implemented. At the end of each example are contact details if you wish to find out more about any of the examples.
**Strymonikos and Ierissos Gulfs, Greece.**
This example describes the study area as a complex multiple use zone, intensively used for tourism and natural resource exploitation. The area is also subject to uncontrolled development and deteriorating environmental conditions. This example illustrates the complexities of a real coastal zone and highlights the need for high quality geographic information in order to make sound management decisions.

[kavala example]

**Cavala Prefecture, Greece.**
This example identifies the need to establish a Coastal Observatory to retain geographic data and to organise a coastal monitoring programme. This example also identifies clearly the need for adequate information management to inform coastal management decisions.

[kavala example]

**Epirus, Greece.**
In this example, "unorganised and dispersed" data is identified as a central problem in the implementation of a coastal management programme. The example describes a GIS and databank set up to address this need.

[epirus example]

**Lochs Long, Duich and Alsh, Scotland.**
This example describes the data management needs resulting from the implementation of the EU Habitats Directive and the need to identify Special Areas of Conservation. The role of GIS in the collection, management, analysis and presentation of relevant data is explained.

[lochs long, duich alsh example]

**Wadden Sea, Netherlands, Germany and Denmark**
In this example, GIS is used to determine the feasibility of the establishment of a Particularly Sensitive Sea Area in the Wadden Sea. GIS is used to map environmental values, maritime risk and, through spatial analysis, identify potential PSSA boundaries.

[wadden sea example]

**Black and Azov Seas**
This example is taken from the Black Sea Environment Programme to develop a spatial plan for the Black and Azov Seas. It explains the context of the use of GIS, the methodology used and a flow diagram displaying the analytical procedures.

[black and azov seas example]
Now you have completed this module, you should be able to:

- describe the functional basis of a GIS
- appreciate the potential uses of GIS in ICM
- consider the benefits and shortcomings of using GIS for ICM
- outline the key data quality issues involved in using GIS
- develop a strategy to implement an effective GIS

Hopefully, you have achieved all the learning outcomes and enjoyed working through the module. It is particularly important that you feel able to apply the ideas presented here to your own role. If not, then please re-visit relevant sections of the module, or contact the COASTLEARN helpdesk.

Sources - Links

**Links to journals and magazines**

GeoEurope [http://www.geoplace.com](http://www.geoplace.com)

Online GIS magazine [http://GIS.about.com/science/qis](http://GIS.about.com/science/qis)

Geographic Information News [http://www.ginews.co.uk](http://www.ginews.co.uk)

**Links to data sources**

The European virtual coastal and marine data warehouse [http://www.coastbase.org](http://www.coastbase.org)

Global datasets [http://www.terraserver.com](http://www.terraserver.com)

SPOT satellite images [http://www.spotimage.com](http://www.spotimage.com)


Environmental information in Central and Eastern Europe and the newly independent states [http://www.grida.no/envin](http://www.grida.no/envin)


Association for Geographic Information [http://www.agi.org.uk](http://www.agi.org.uk)

Link site to 40+ data suppliers [http://www.vtt.fi/aut/rs/virtual/pter.html](http://www.vtt.fi/aut/rs/virtual/pter.html)

GIS resource list [http://www.geo.ed.ac.uk/home/giswww.html](http://www.geo.ed.ac.uk/home/giswww.html)
Link to full copy of PSSA feasibility report: http://cwss.www.de/tgc/pssa/pssa.html
ESRI Marine and Coast Community http://www.esri.com/industries/marine/index.html


Links to GIS suppliers
Autodesk Ltd http://www.autodesk.com/gis
Mapinfo Ltd http://www.mapinfo.com
Idrisi Project http://www.idrisi.clarku.edu
ESRI Ltd (manufacturer of ARC/INFO GIS) http://www.esriuk.com
Intergraph Ltd http://www.intergraph.com

Free GIS software
http://www.freegis.org/

Links to more educational material
Centre for Geographic Information and Analysis http://www.ncgia.ucsb.edu/
ESRI Virtual Campus courses http://www.campus.esri.com

Sources - References

General GIS texts


**Coastal and Marine GIS**


**Answers**

*Use the space below to write down how you would define GIS:*

**ANSWER**

There are numerous definitions of GIS and none are universally agreed. Here are two examples:

- 'a set of processes executed on geographically referenced data as well as non-spatial data which aid in the process of decision making'
- 'a system for capturing, storing, checking, integrating, manipulating, analysing and displaying data which are spatially referenced to the Earth'

Alternatively, it is possible to define GIS through reference to their specific functions. For example, a GIS is able to (Davis, 1996):

- Facilitate data collection
- Store data in an efficient manner
- Manage data in a common database
- Retrieve data for viewing or analysis
- Convert data to enable enhanced analysis
- Undertake spatial analysis
- Model the real world to identify relationships and patterns
- Display data to improve understanding

**Complete the table below to consider some of the advantages and disadvantages of raster and vector format**

**ANSWER**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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</table>
In summary, raster format GIS accept raw remotely sensed data more easily and usefully than vector format GIS. However, vector format GIS tend to be easier to use, but less easy to populate with raw data. Vector format GIS also produce more map-like output. When selecting a format of GIS for use, it is important to consider the use that will be made of the GIS and to select a format which has qualities that reinforce the aim of the project rather than work against it.

<table>
<thead>
<tr>
<th>Raster</th>
<th>Vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple data structure</td>
<td>Simple overlay functions</td>
</tr>
<tr>
<td>Remotely sensed data is raster</td>
<td>Maintains shape well</td>
</tr>
<tr>
<td>Complex overlay functions</td>
<td>Precise georeferencing</td>
</tr>
<tr>
<td>Memory intensive</td>
<td>Complex database structures</td>
</tr>
<tr>
<td>Distorts shapes</td>
<td></td>
</tr>
<tr>
<td>Imprecise georeferencing</td>
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**What are the specific implications of these facts of life for GIS use for ICM?**

**ANSWER**

Specific implications for GIS used in ICM include:

- GIS results may assume additional importance due to the complexity of coastal realities
- ‘Coastal’ GIS output needs to be treated with extra caution
- Decision-makers need to be ‘GIS aware’

More generally, the facts of life outlined by Bowers (1992) suggests that without appropriate understanding of GIS data management processes and GIS output, decisions assisted by GIS can be flawed or inappropriate.

**QUESTION 1 What information do you need in order to help produce the management plan?**

**QUESTION 2 Consider how to identify areas of use-use and use-environment conflict. How would you gain this data?**

**ANSWER**

This data is spatial, so existing maps would be a good place to start. In particular, suitable sources might be:

- Topographic maps - ensure scale is appropriate
- Hydrographic charts - ensure scale is appropriate
- Ariel photographs showing use activities
- Observation / survey - to see where use occurs
- Interview survey with users to discover where they undertake their activity

With any of these data sets it is important that you make sure the accuracy of the spatial component of the data is accurate enough for the study. It is also important to get a temporal fix to appreciate when the data is valid (e.g. swimming is probably only a summer activity). With existing maps there may also be copyright restrictions on their use, so check before using them.

**QUESTION 3 Using the structure presented earlier in the module, prepare a brief project plan to show how you would use the GIS to identify areas of**
The information you need is likely to include:

- The location of the nature conservation sites
- The location of shipping and sailing channels
- The location of swimming areas
- The locations where the uses are in conflict
- The locations where nature conservation sites are at risk from other uses
- The location of infrastructure (access to the sea, roads, rail, footpaths, etc)
- Land ownership
- Administrative boundaries
- Current policies
- Physical processes and coastal change

Applying the structure presented earlier:

**Aim**: to identify areas of coastal conflict

**Data needs**: The location of the nature conservation sites, shipping and recreational lanes, and swimming areas.

**Model**: each set of location data should be stored as an individual data layer. These can then be overlaid to reveal where the areas of overlap are. These areas are the places that uses overlap, it is important to note that they may not be the same as areas in which conflict occurs. This information will need to be interpreted to be useful.

**Assemble data**: use techniques outlined in answer 2 to collect the data.

**Enter data**: enter the data into the GIS using appropriate methods. This will vary according to the data source, however, is likely to include scanning and manual digitising.

**Interrogate the GIS**: use appropriate aspects of the GIS software to overlay the data layers to derive an image showing areas of overlap (indicative of conflict).

**Make decision**: the locations of conflict will allow you to make a decision regarding how the conflict should be managed.