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Geographical Information Systems (GIS)

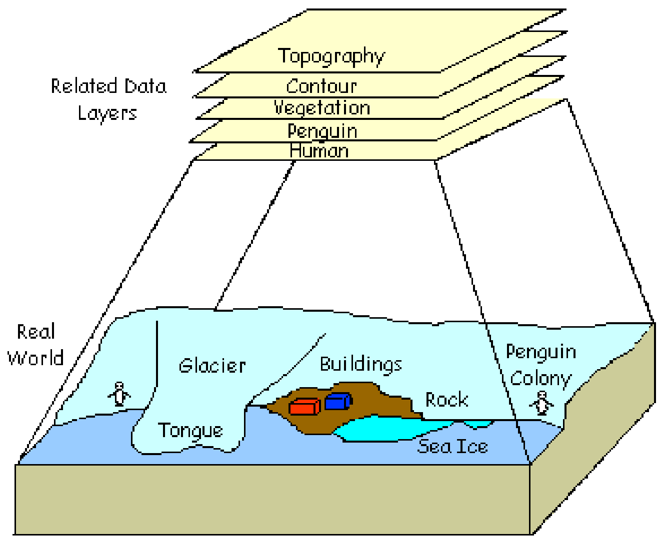
Bjarne Sivertsen[1] and Lidia Morawska[2]

1) Norwegian Institute for Air Research, Kjeller, Norway
2) Queensland University of Technology, Australia

Presented at

Clean Air for Asia training programme

Bangkok May – June 2006
Ho Chi Minh City, October – November 2006



Geographical Information Systems (GIS)

1 Introduction

This paper is part of the presentations prepared for two training seminars organised by the Stockholm Environment Institute (SEI). SEI was responsible for the overall coordination and management of the project. The training workshops, which were held in Bangkok in June 2006 and in Ho Chi Minh City in October-November 2006, were organised in collaboration with the Clean Air Network for Asia (CATNet). CATNet is part of the Clean Air Initiative for Asian Cities (CAI Asia), which has undertaken a series of activities to enhance the capacity of national and local governmental authorities in Asia

The seminar presented a summary of the air quality monitoring and management programme, which has been developed around the world and in Asia in particular. This report presents the geographical information system (GIS) used in many of the air quality data monitoring and management systems. Examples were presented based on the application of such system. The presentation was prepared in a co-operation between Bjarne Sivertsen at the Norwegian Institute for Air Research (NILU) and Lidia Morawska at the Queensland University of Technology in Australia.

2 What is GIS

A geographical information system (GIS), or more commonly referred to as a geospatial information system is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth.

In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically refrenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, and present the results of all these operations.

3 GIS components and architecture

The main components of the GIS system are:

- The hardware system
- Software
- Spatial data
- People and expertise

Hardware is the computer on which a GIS operates. Today, GIS runs on a wide range of hardware types, from centralized computer servers to desktop computers used in stand-alone or networked configurations.

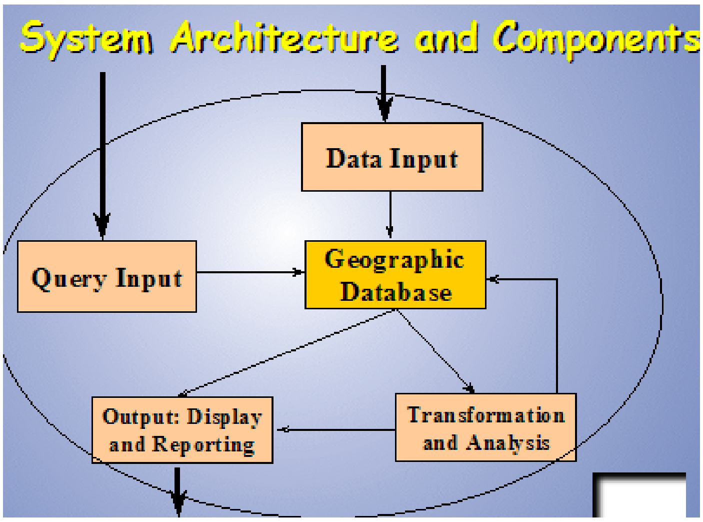
GIS **software** provides the functions and tools needed to store, analyse, and display geographic information. Key software components are

- A database management system (DBMS)
- Tools for the input and manipulation of geographic information
- Tools that support geographic query, analysis, and visualization
- Graphical user interface (GUI) for easy access to tools

Data is maybe the most important component of the GIS system. Geographic data and related tabular data can be collected in-house or bought from a commercial data provider. Most GISs employ a DBMS to create and maintain a database to help organize and manage data.

GIS technology is of limited value without the people who manage the system and to develop plans for applying it. GIS users range from technical specialists who design and maintain the system to those who use it to help them do their everyday work.

The system below indicates the components and the typical data flow in the GIS system.



4 GIS: maps and features

The GIS systems are generally divided into a raster or vector model type.

Raster is a method for the storage, processing and display of spatial data. Each area is divided into rows and columns, which form a regular grid structure. Each cell must be rectangular in shape, but not necessarily square. Each cell within this matrix contains location co-ordinates as well as an attribute value. The spatial location of each cell is implicitly contained within the ordering of the matrix, unlike a vector structure, which stores topology explicitly. Areas containing the same attribute value are recognised as such, however, raster structures cannot identify the boundaries of such areas as polygons.

Vector is a data structure, used to store spatial data. Vector data is comprised of lines or arcs, defined by beginning and end points, which meet at nodes. The locations of these nodes and the topological structure are usually stored explicitly. Features are defined by their boundaries only and curved lines are represented as a series of connecting arcs. Vector storage involves the storage of explicit topology, which raises overheads, however it only stores those points, which define a feature, and all space outside these features is 'non-existent'.

A vector based GIS is defined by the vectorial representation of its geographic data. According with the characteristics of this data model, geographic objects are explicitly represented and, within the spatial characteristics, the thematic aspects are associated.

A sophisticated GIS Map Server may provide the ability to generate highly detailed real-time map images. The map images serve as a background, which provides contextual information. Either static or dynamic icons may be placed on top of the images to provide real-time application-specific and interactive functionality.

The GIS platform provides easy access to the data and gives a perfect and easily understandable data presentation tool. Information on all map related data such as area use, traffic density and emissions could be accessed through the map. The GIS system can display results of model calculations as a map can be used for public information on pollution levels at different parts of a city

The GIS features simplifies a number of functions such as:

1. Easier to locate sources
2. Map topographical features
3. Position roads and streets
4. Locate buildings and industries
5. Map population distributions
6. Locate monitoring stations
7. Area distribute consumption data and emissions
8. Possible to search for geographically linked data

5 GIS functionality

The GIS (Geographical Information System) functionality of the air quality management system is designed to offer several possibilities for understanding the problems of air pollution.

- The GIS makes it easier to place the air pollution sources at the correct location, for example by making it easy to display the total network of road links in a city.
- GIS presentation of area-distributed consumption of fossil fuels and direct emissions gives a good overview of where to expect high impact of air pollution.

- Viewing the measurement stations on a map with the pollution sources will give an idea of what concentrations one may expect to find at the stations for a given wind direction.
- The GIS makes it easier to search for geographically linked data in the database.
- Displaying results of model calculations as a map can be used for public information on pollution levels at different parts of a city.

There are three types of data that can be displayed on the map: shape themes, ENSIS themes and data set.

6 GIS in air pollution modelling

The main objective of a modern environmental surveillance platform is to enable direct data and information transfer and obtain a remote quality control of the data collection.

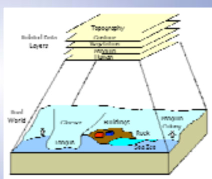
The system combine monitoring, data presentation and modelling in one package, which enable the user not only to present and evaluate the present situation, but also to undertake environmental planning for a sustainable future. The GIS platform, on which the system is operated, provides easy access to the data and gives a perfect and easily understandable data presentation tool.

Input data such as emission rates, wind and turbulence are collected and presented on map co-ordinates in a GIS system. Different dispersion models produce concentration distributions also presented on a GIS system.

The NILU developed AirQUIS system provides easy access to the data and gives a perfect and easily understandable data presentation using a GIS based platform. The system combine monitoring, data presentation and modelling in one package, which enable the user not only to present and evaluate the present situation, but also to undertake environmental planning for a sustainable future.

Geographical Information System

GIS



Bjarne Sivertsen,
Norwegian Institute
or Air Research,
NILU

Lidia Morawska
International Laboratory for Air Quality and Health
Queensland University of Technology

UNIT 7

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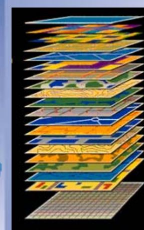
What Is GIS?



An Organized Collection of:

- computer hardware
- computer software
- geographic data and
- trained personnel

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Geographic information system (GIS):

A computer system designed for storing, manipulating, analysing, and displaying data in a geographic context.

Analysis that combine relational data bases with spatial interpretation and outputs often in form of maps.

A more elaborate definition:
- programmes for capturing, storing, checking, integrating, analysing and displaying data about the earth that is spatially referenced .

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The GIS system can :

- **Organize geographic data into layers.**
- **Link spatial data with tabular attribute data.**
- **Provide a common geo referencing system.**
- **Perform spatial analysis.**
- **Provide display of geographic information.**

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The GIS applications can:

manage, analyze, communicate

- enable **automation** map production
  - calculation of areas, distances, route lengths
  - measurement of slope, aspect, view shed
  - logistics: route planning, vehicle tracking, traffic management
- allow **integration** of e.g. maps and air photos.
- **communicate** of complex spatial patterns (e.g environmental sensitivity).
- **spatial queries** (how many live in specified zone)
- **spatial modelling** (*what if* scenarios for transport planning, air quality, resource management etc.

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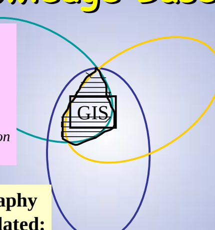
Knowledge Base for GIS

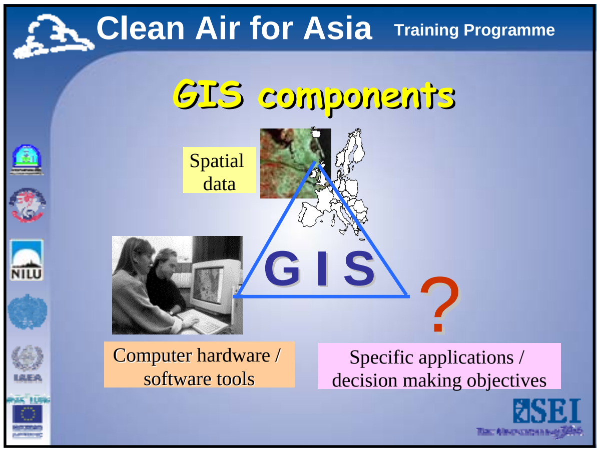
Computer Science/MIS
graphics
visualization
database
system administration
security

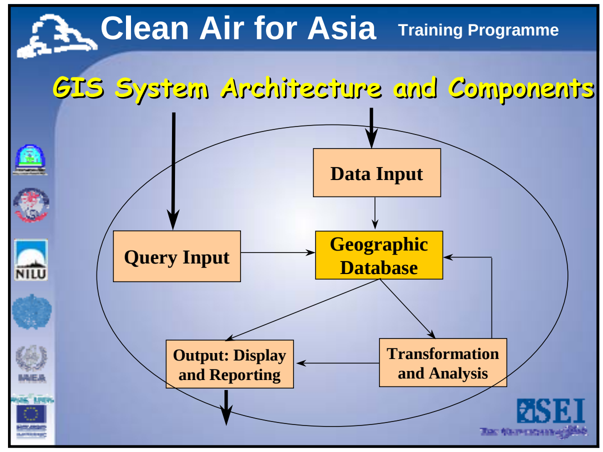


Application Area:
public admin.
planning
geology
mineral exploration
forestry
site selection
marketing
civil engineering
criminal justice
surveying

Geography and related:
cartography
geodesy
photogrammetry
landforms
spatial statistics.

The convergence of technological fields and traditional disciplines.


Clean Air for Asia Training Programme
GIS components
Spatial data
GIS
?
Computer hardware / software tools
Specific applications / decision making objectives
SEI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GIS System Architecture and Components
Data Input
Query Input
Geographic Database
Output: Display and Reporting
Transformation and Analysis
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Types of data
Spatial
non-spatial
Maps
Schematic diagrams
Images
Oblique photographs
Videography
Films
Postcodes/ZIP codes
Financial statements
KT1 2EE
RH8 9AA
SW1P 3AD
£12,000 23.45 56789
£23,456 12.45 23456
£45,987 29.57 87634
SEI


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What makes data spatial?
Grid co-ordinate
Placename
Latitude / Longitude
Postcode
Description
Distance & bearing
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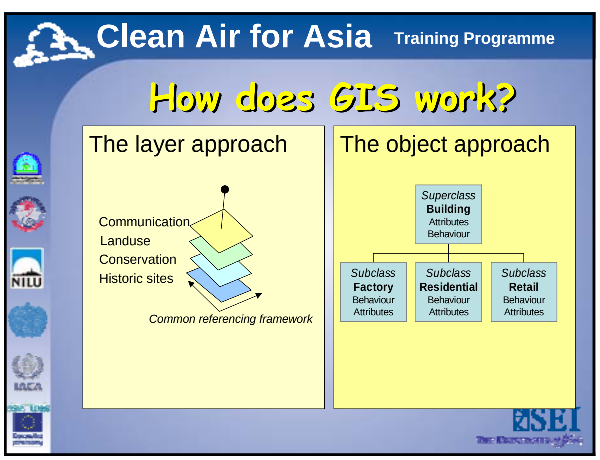
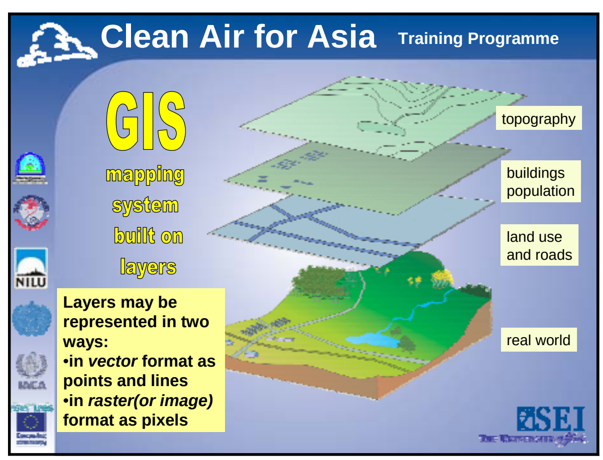

Clean Air for Asia Training Programme
How does GIS work?
The layer approach
Communication
Landuse
Conservation
Historic sites
Common referencing framework
The object approach
Superclass
Building
Attributes
Behaviour
Subclass
Factory
Behaviour
Attributes
Subclass
Residential
Behaviour
Attributes
Subclass
Retail
Behaviour
Attributes
SEI


Clean Air for Asia Training Programme
GIS
mapping system built on layers
topography
buildings population
land use and roads
real world
Layers may be represented in two ways:
•in vector format as points and lines
•in raster(or image) format as pixels
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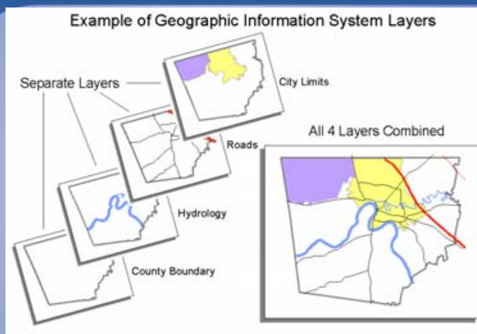

All geographic data has 4 properties: projection, scale, accuracy and resolution

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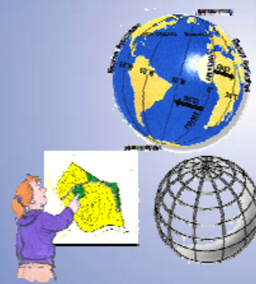
Geographical Data Features



- Grid
- Topography
- Population data
- Receptor points
- Building points

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Spatial and Attribute Data

- Spatial data *(where)*
  - specifies location
  - stored in a ***shape file*** in Arcview
- Attribute (descriptive) data *(what, how much, when)*
  - specifies characteristics at that location, natural or human-created
  - stored in a data base ***table***

GIS systems traditionally maintain spatial and attribute data separately, then "join" them for display or analysis

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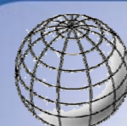

Key properties of spatial data

- **Projection:** curved 3-D surface of the earth represented by X,Y coordinates on a 2-D flat map/screen
- **Scale:** the ratio of distance on a map to the equivalent distance on the ground
- **Accuracy:** how well does the database info match the real world (*Positional, Consistency and Completeness)*
- **Resolution:** the size of the smallest feature able to be recognized

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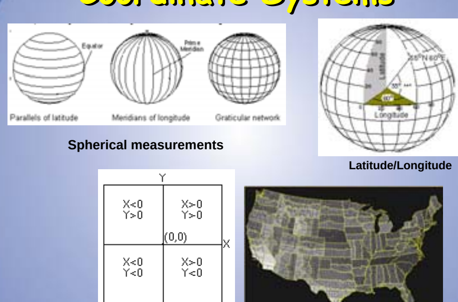
Coordinate Systems



Spherical measurements

Latitude/Longitude

Cartesian coordinate system

State Plane zones

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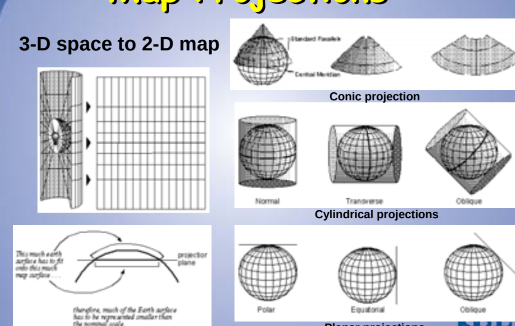
Map Projections

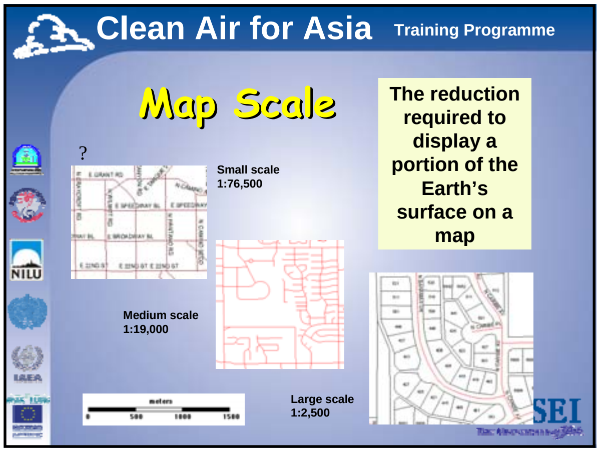
3-D space to 2-D map

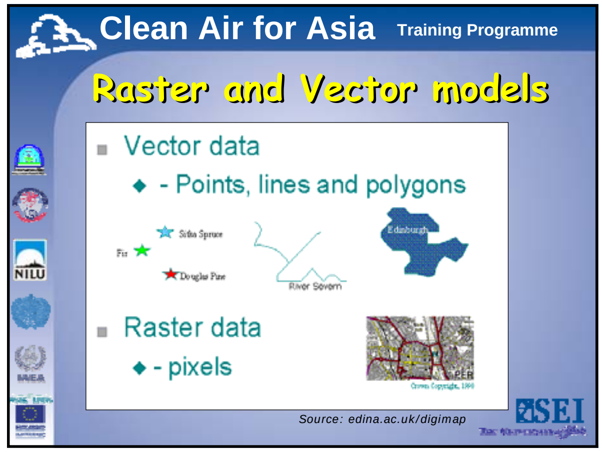


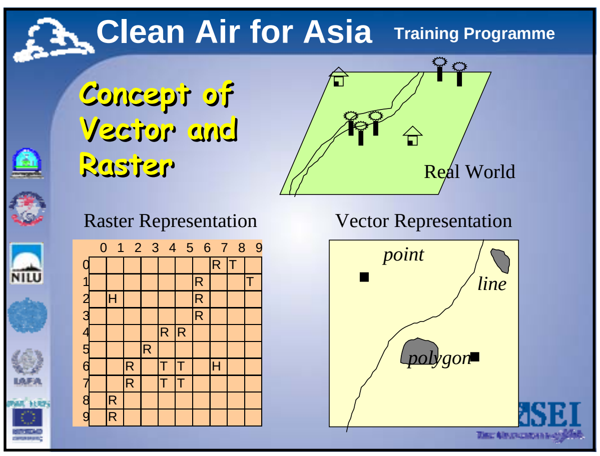
Conic projection

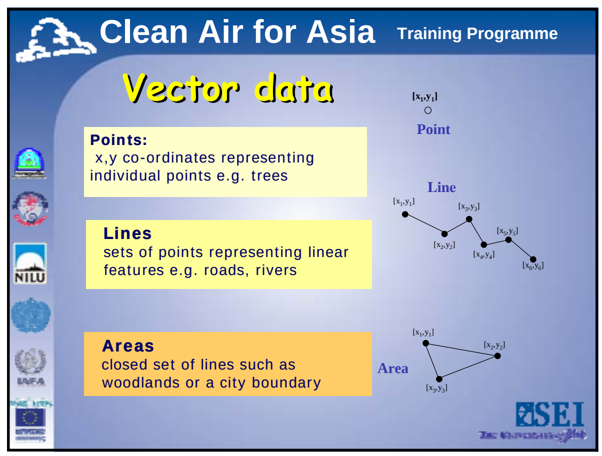
Cylindrical projections

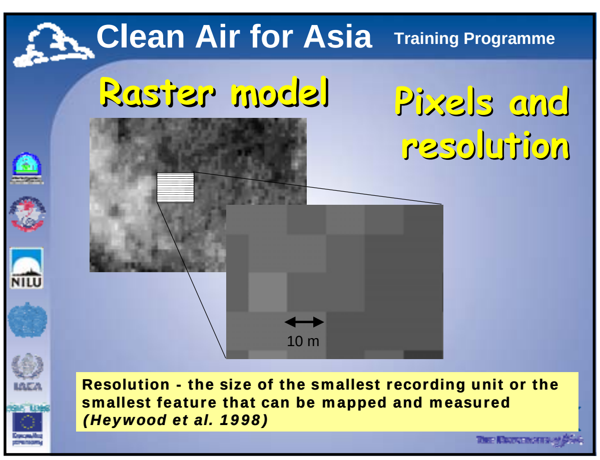
Planar projections

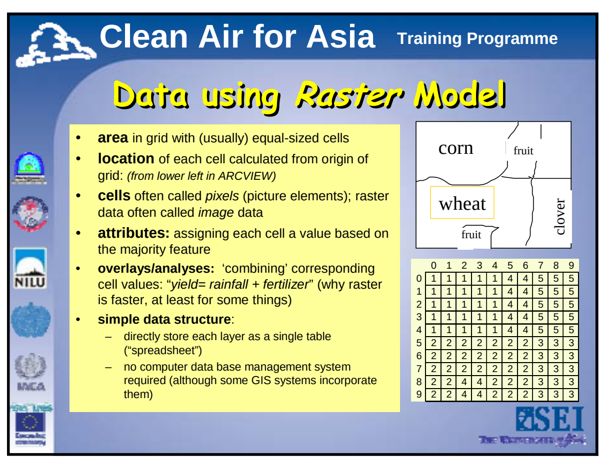

Clean Air for Asia Training Programme
Map Scale
The reduction required to display a portion of the Earth's surface on a map
?
Small scale 1:76,500
Medium scale 1:19,000
Large scale 1:2,500
meters
0 500 1000 1500
SEI

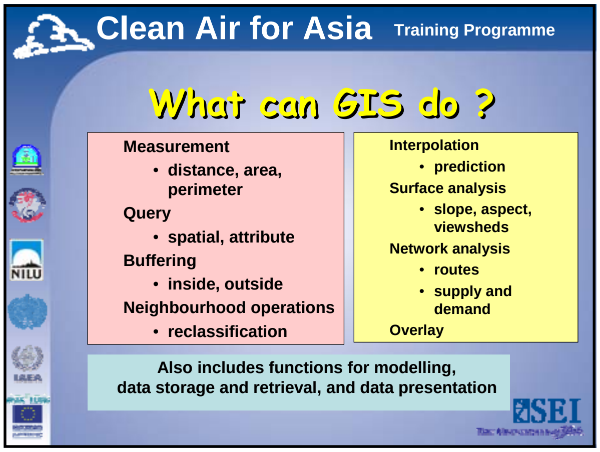

Clean Air for Asia Training Programme
Raster and Vector models
Vector data
- Points, lines and polygons
Raster data
- pixels
Source: edina.ac.uk/digimap
SEI

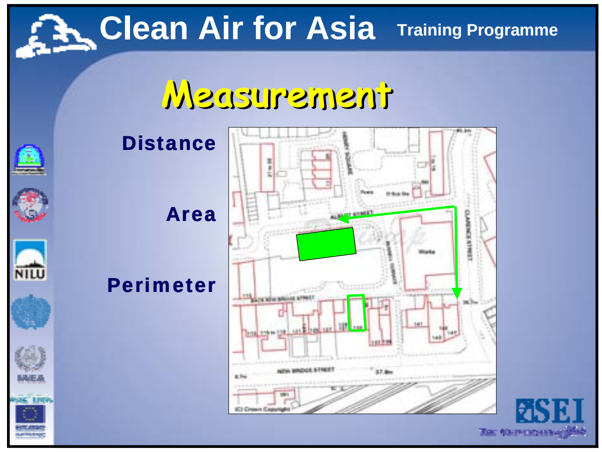

Clean Air for Asia Training Programme
Concept of Vector and Raster
Real World
Raster Representation
Vector Representation
0 1 2 3 4 5 6 7 8 9
0 R T
1 R T
2 H R
3 R
4 R R
5 R
6 R T T H
7 R T T
8 R
9 R
point
line
polygon
SEI

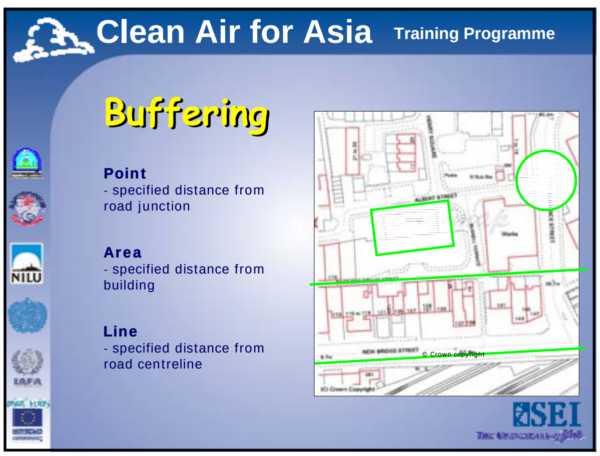

Clean Air for Asia Training Programme
Vector data
Points:
x,y co-ordinates representing individual points e.g. trees
Lines
sets of points representing linear features e.g. roads, rivers
Areas
closed set of lines such as woodlands or a city boundary
Point
Line
Area
SEI

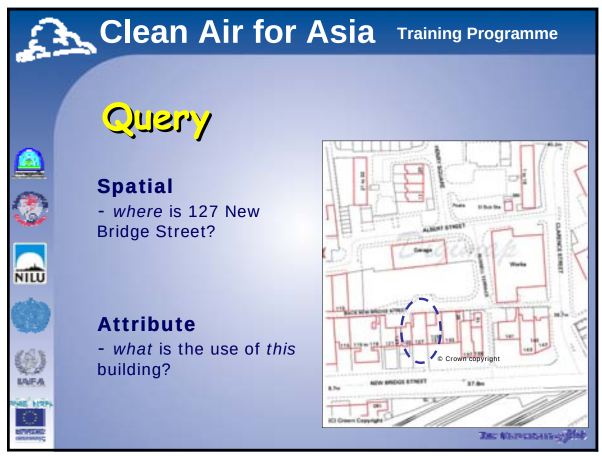

Clean Air for Asia Training Programme
Raster model
Pixels and resolution
10 m
Resolution - the size of the smallest recording unit or the smallest feature that can be mapped and measured
(Heywood et al. 1998)

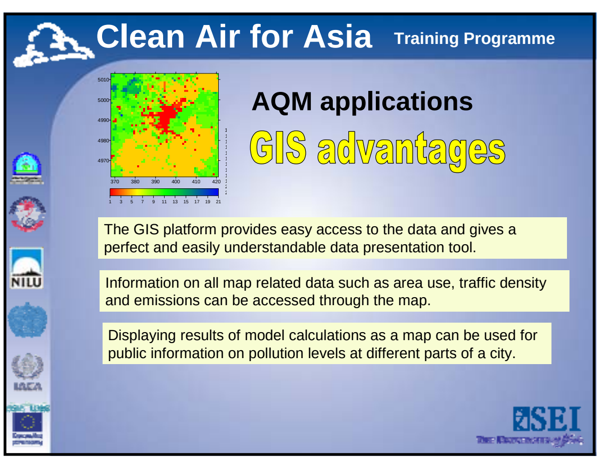

Clean Air for Asia Training Programme
Data using Raster Model
• area in grid with (usually) equal-sized cells
• location of each cell calculated from origin of grid: (from lower left in ARCVIEW)
• cells often called pixels (picture elements); raster data often called image data
• attributes: assigning each cell a value based on the majority feature
• overlays/analyses: 'combining' corresponding cell values: "yield= rainfall + fertilizer" (why raster is faster, at least for some things)
• simple data structure:
– directly store each layer as a single table ("spreadsheet")
– no computer data base management system required (although some GIS systems incorporate them)
corn
fruit
wheat
fruit
clover
0 1 2 3 4 5 6 7 8 9
0 1 1 1 1 1 4 4 5 5 5
1 1 1 1 1 1 4 4 5 5 5
2 1 1 1 1 1 4 4 5 5 5
3 1 1 1 1 1 4 4 5 5 5
4 1 1 1 1 1 4 4 5 5 5
5 2 2 2 2 2 2 2 3 3 3
6 2 2 2 2 2 2 2 3 3 3
7 2 2 2 2 2 2 2 3 3 3
8 2 2 4 4 2 2 2 3 3 3
9 2 2 4 4 2 2 2 3 3 3
SEI


Clean Air for Asia Training Programme
What can GIS do ?
Measurement
• distance, area, perimeter
Query
• spatial, attribute
Buffering
• inside, outside
Neighbourhood operations
• reclassification
Interpolation
• prediction
Surface analysis
• slope, aspect, viewsheds
Network analysis
• routes
• supply and demand
Overlay
Also includes functions for modelling, data storage and retrieval, and data presentation
NILU
IAEA
SEI


Clean Air for Asia Training Programme
Measurement
Distance
Area
Perimeter
NILU
IAEA
SEI


Clean Air for Asia Training Programme
Buffering
Point
- specified distance from road junction
Area
- specified distance from building
Line
- specified distance from road centreline
NILU
IAEA
SEI


Clean Air for Asia Training Programme
Query
Spatial
- where is 127 New Bridge Street?
Attribute
- what is the use of this building?
NILU
IAEA
SEI


Clean Air for Asia Training Programme
AQM applications
GIS advantages
The GIS platform provides easy access to the data and gives a perfect and easily understandable data presentation tool.
Information on all map related data such as area use, traffic density and emissions can be accessed through the map.
Displaying results of model calculations as a map can be used for public information on pollution levels at different parts of a city.
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in air pollution studies:
The GIS functionality
✓ Easier to locate sources
✓ Map topographical features
✓ Position roads and streets
✓ Locate buildings and industries
✓ Map population distributions
✓ Locate monitoring stations
✓ Area distribute consumption data and emissions
✓ Possible to search for geographically linked data
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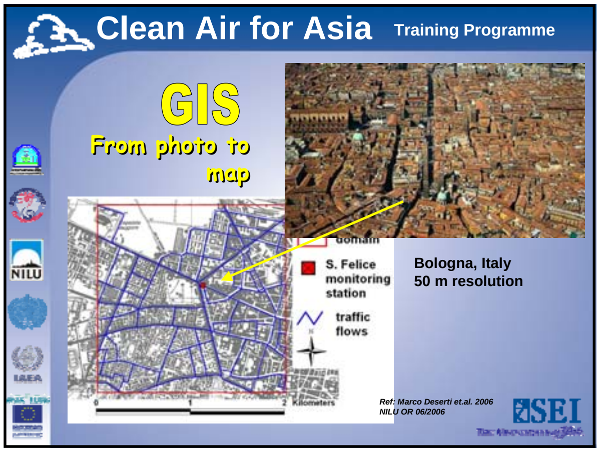
Clean Air for Asia Training Programme
GIS
From photo to map
S. Felice monitoring station
traffic flows
Bologna, Italy
50 m resolution
Ref: Marco Deserti et.al. 2006
NILU OR 06/2006
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GIS zoom functions
look at details..
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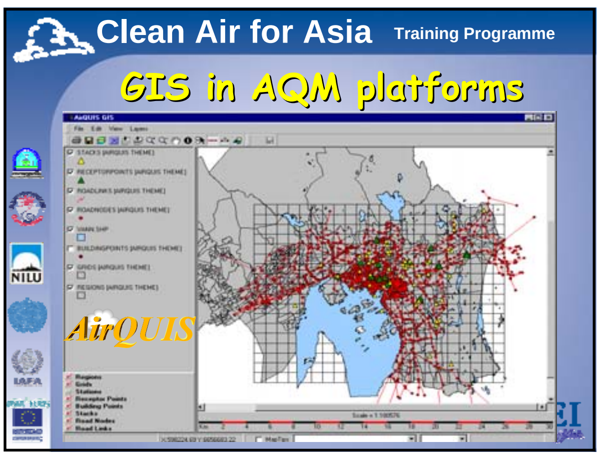
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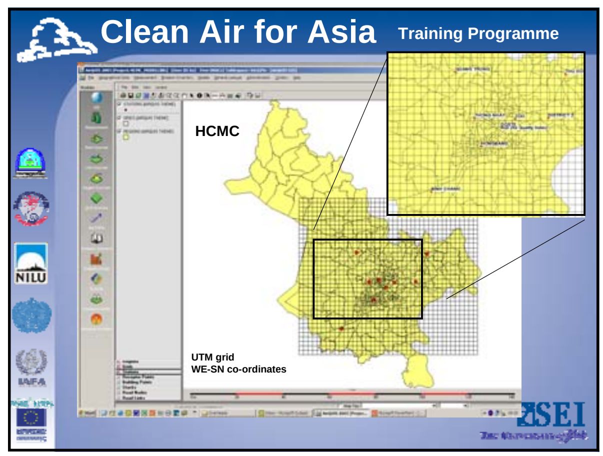
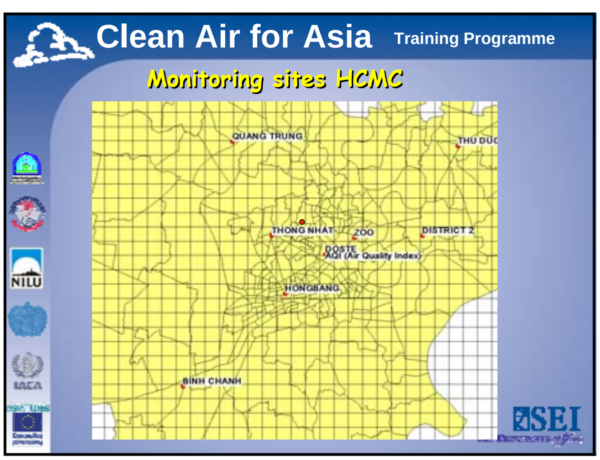
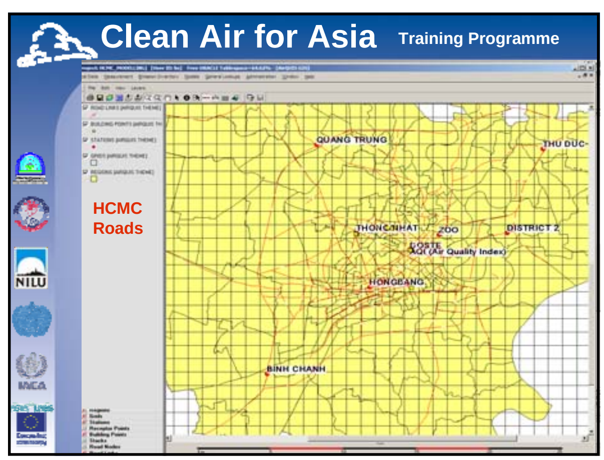
GIS in AQM platforms
AirQUIS
NILU

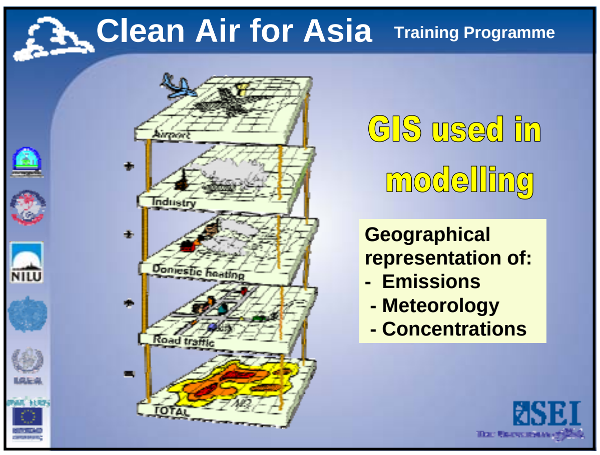

Clean Air for Asia Training Programme
HCMC
UTM grid
WE-SN co-ordinates
NILU

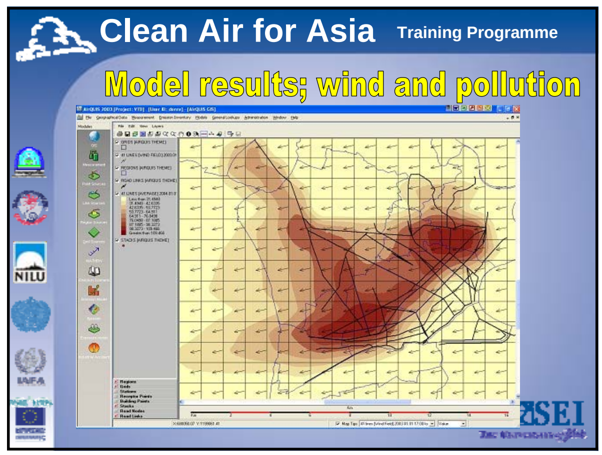

Clean Air for Asia Training Programme
Monitoring sites HCMC
QUANG TRUNG
THU DUC
THONG NHAT
ZOO
DISTRICT 2
DOSTE
AQI (Air Quality Index)
HONGBANG
BINH CHANH
NILU
SEI


Clean Air for Asia Training Programme
HCMC
Roads
QUANG TRUNG
THU DUC
THONG NHAT
ZOO
DISTRICT 2
DOSTE
AQI (Air Quality Index)
HONGBANG
BINH CHANH
NILU

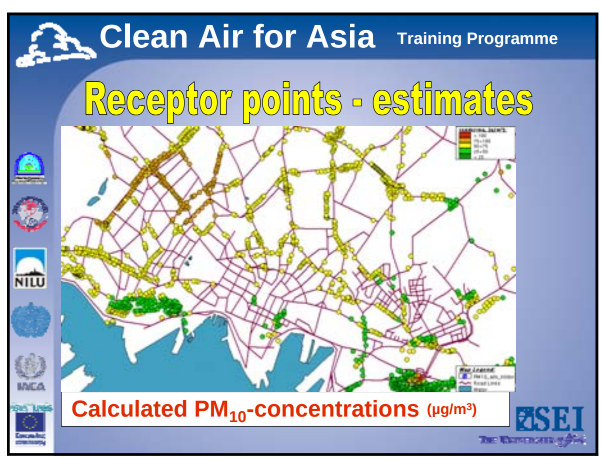

Clean Air for Asia
Training Programme
THU DUC
THONG NHAT
ZOO
DISTRICT 2
DOSTE
AQI (Air Quality Index)
HONGBANG
BINH CHANH


Clean Air for Asia
Training Programme
Areas (Wards), roads and water
HOC MON
GOVAP
THU DUC
TAN BINH
BINH THANH
BINH CHANH
QUAN 2
QUAN 4
QUAN 7
NILU


Clean Air for Asia
Training Programme
GIS used in modelling
Geographical representation of:
- Emissions
- Meteorology
- Concentrations
Airport
Industry
Domestic heating
Road traffic
TOTAL
SEI
NILU


Clean Air for Asia
Training Programme
Model results; wind and pollution
SEI
NILU


Clean Air for Asia
Training Programme
Calculated concentrations
NO2 concentr.
Oslo, Norway
SEI
NILU


Clean Air for Asia
Training Programme
Receptor points - estimates
Calculated PM_{10}-concentrations (µg/m³)
SEI
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Examples of Applied GIS

- **Urban Planning, Management & Policy**
  - Zoning, subdivision planning
  - Land acquisition
  - Economic development
  - Code enforcement
  - Housing renovation programs
  - Emergency response
  - Crime analysis
  - Tax assessment
- **Environmental Sciences**
  - Monitoring environmental risk
  - Modeling stormwater runoff
  - Management of watersheds, floodplains, wetlands, forests, aquifers
  - Environmental Impact Analysis
  - Hazardous or toxic facility siting
  - Groundwater modeling and contamination tracking
- **Political Science**
  - Redistricting
  - Analysis of election results
  - Predictive modeling
- **Civil Engineering/Utility**
  - Locating underground facilities
  - Designing alignment for freeways, transit
  - Coordination of infrastructure maintenance
- **Business**
  - Demographic Analysis
  - Market Penetration/ Share Analysis
  - Site Selection
- **Education Administration**
  - Attendance Area Maintenance
  - Enrollment Projections
  - School Bus Routing
- **Real Estate**
  - Neighborhood land prices
  - Traffic Impact Analysis
  - Determination of Highest and Best Use
- **Health Care**
  - Epidemiology
  - Needs Analysis
  - Service Inventory

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Thank you !


GIS - find your way!

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Norwegian Institute for Air Research

NILU
POBox 100
No-2027 Kjeller
Norway
Fax: +4763898050
E-mail: nilu@nilu.no

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Representing Data with *Raster* and *Vector* Models

Raster Model

- area is covered by grid with (usually) equal-sized, square cells
- attributes are recorded by assigning each cell a single value based on the majority feature (attribute) in the cell, such as land use type.
- *Image* data is a special case of raster data in which the attribute is a reflectance value from the geomagnetic spectrum
  - cells in image data often called *pixels* (picture elements)
- **Vector Model**

The fundamental concept of vector GIS is that all geographic features in the real work can be represented either as:

- **points or dots (*nodes*)**: trees, poles, fire plugs, airports, cities
- **lines (*arcs*):** streams, streets, sewers,
- **areas (*polygons*):** land parcels, cities, counties, forest, rock type

Because representation depends on shape, ArcView refers to files containing vector data as *shapefiles*

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Vector Model general concept

The fundamental concept of vector GIS is that all geographic features in the real work (or on a map) can be represented either as:

- **points or dots (*nodes*)**: trees, poles, fire plugs, airports, cities
- **lines (*arcs*):** streams, streets, sewers,
- **areas (*polygons*):** land parcels, cities, counties, forest, rock type

Which is used in a particular instance depends on scale, among other things: airport or manhole may be a point or polygon

Because representation depends on shape, ArcView refers to files containing spatial data as *shapefiles* (altho. these used for both vector and raster)