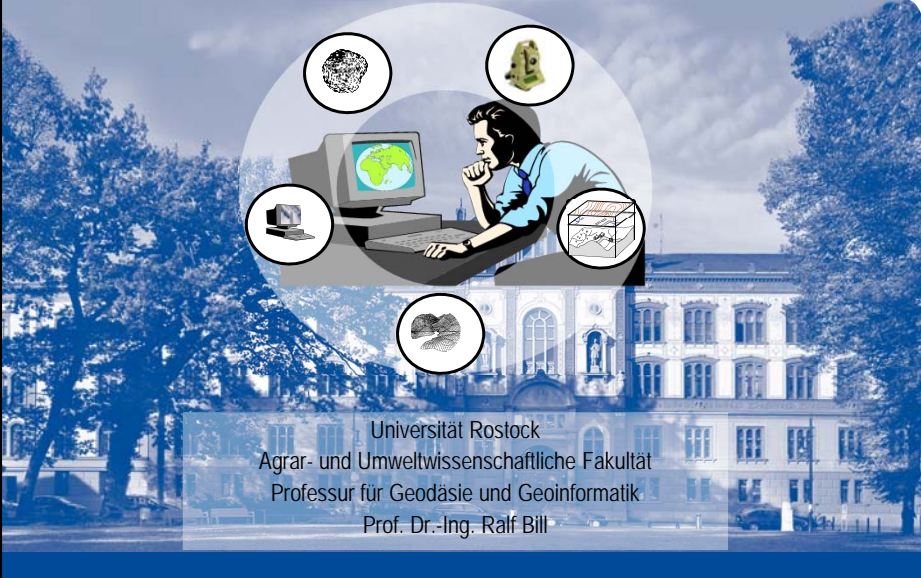


Universität Rostock Traditio et Innovatio **GIS – a short introduction**



Universität Rostock
Agrar- und Umweltwissenschaftliche Fakultät
Professur für Geodäsie und Geoinformatik
Prof. Dr.-Ing. Ralf Bill

Universität Rostock Traditio et Innovatio **Content**

- Terms and definitions
- IMAP – the processing chain in a GIS
- Advanced technologies
- Applications

Introduction to spatial information processing
Ralf Bill (Editor)



Textbook for international GIS courses


Internal Report, Volume 17, 2019
Rostock University
Faculty of Agricultural and Environmental Sciences,
Chair of Geodesy and Geoinformatics

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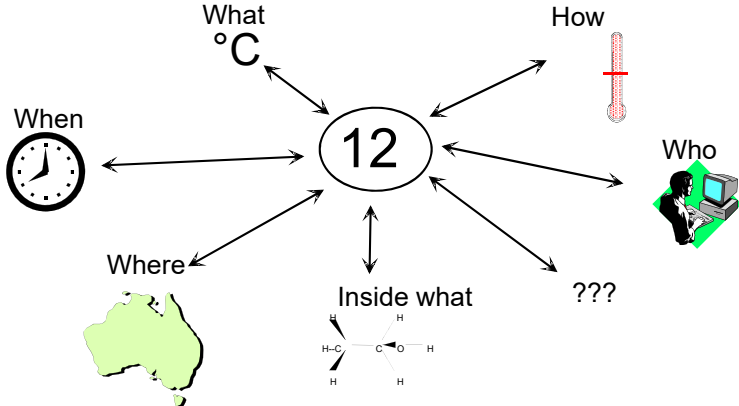
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TERMS AND DEFINITIONS

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Information = data + context



Reference: K. Greve, 1995

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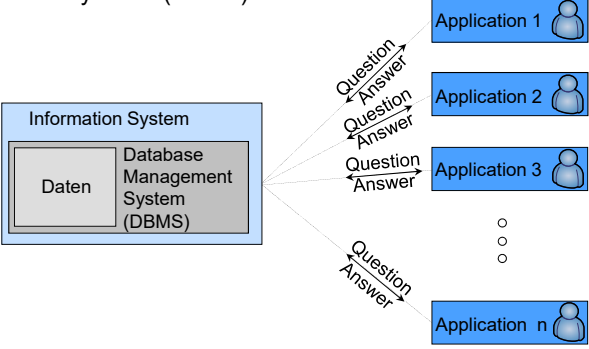


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Information systems


- A **system** is a set of elements that are interrelated.
- **Information systems** are general tools to manage and analyse data.
- **Information systems** are based on databases and their database management systems (DBMS).



- An **information system** is basically a “question / answer” system for a set of data.

Reference: R. Bill, 2016


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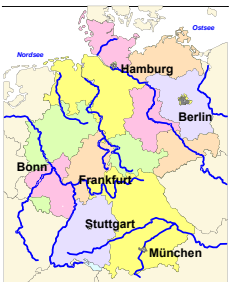
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'Geo' – the magic linking element



a) Global




b) Regional



c) Local (horizontal)


gejo..., Gelo...,
(greek. gē, gaīa) "Earth"



All information is somehow related to the Earth or parts of it, i.e. it is spatially referenced.

Reference: R. Bill, 2016

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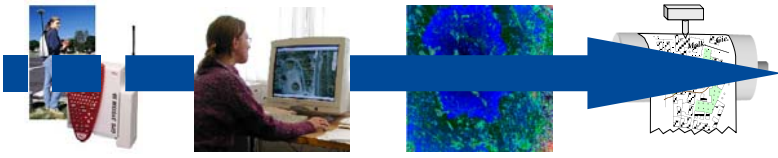
Definition Geographic Information System (GIS) I

GIS is a **computer-based system** to

- **I** nput,
- **M** anage,
- **A** nalyse and
- **P** resent


spatial information.

I	Hardware
M	Software
A	Data
P	User



I
M
A
P


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Definition GIS II Map + DB in the computer

Map = graphic data



Database = attributes


Building			
12			
15			
16			
Streets			
Parcel			
125/1			
125/3			
125/2			
xxx			



Feature - *Agricultural field plot*

- *Feature ID*
- *Geometry* – *Perimeter polygon* ($x_1, y_1, \dots, x_n, y_n$)
- *Topology* – *Area, neighbours*
- *Attributes* – *Owner, current crops, area size*
- ..
- *Graphics* – light yellow

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Primary metrics:
direct spatial reference

ISO 19111 (Coordinate reference systems (CRS))

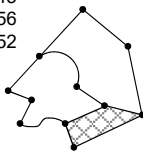
Coordinates or construction rules

- Properties:
 - defined metrics
 - defined reference system
 - high accuracy expected
 - multidimensional search criteria


Coordinates

x	y	z
64695.740	23685.123	123.768
64623.546	23626.876	125.645
64593.341	23653.265	122.756
64695.740	23685.123	121.752

x	y
64695.740	23685.123
64623.546	23626.876
64593.341	23653.265
64695.740	23685.123



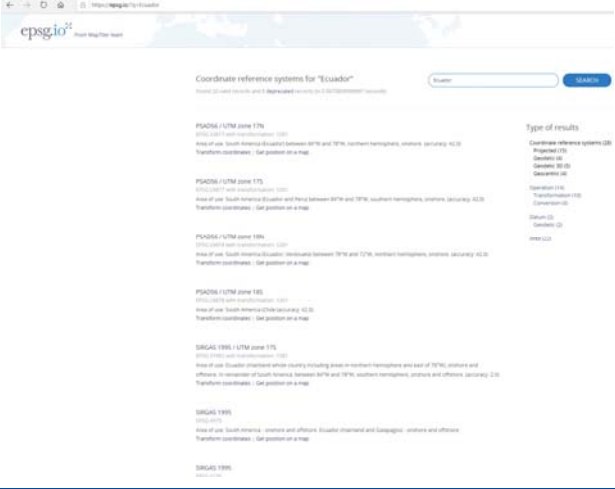
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Coordinate Reference Systems
- Ecuador

- **EPSG database**




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Coordinate Reference Systems - Ecuador



```

PROJCS["PSAD56 / UTM zone 18N",
GEOGCS["PSAD56",
DATUM["Provisional_South_American_Datum_1956",
SPHEROID["International 1924",6378388,297,
AUTHORITY["EPSG","7022"]],
TOWGS84[-288,175,-376,0,0,0,0],
AUTHORITY["EPSG","6248"]],
PRIMEM["Greenwich",0,
AUTHORITY["EPSG","8901"]],
UNIT["degree",0.0174532925199433,
AUTHORITY["EPSG","9122"]],
AUTHORITY["EPSG","4248"]],
PROJECTION["Transverse_Mercator"],
PARAMETER["latitude_of_origin",0],
PARAMETER["central_meridian",-75],
PARAMETER["scale_factor",0.9996],
PARAMETER["false_easting",500000],
PARAMETER["false_northing",0],
UNIT["metre",1,
AUTHORITY["EPSG","9001"]],
AXIS["Easting",EAST],
AXIS["Northing",NORTH],
AUTHORITY["EPSG","24818"]]
                    
```

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Secondary metrics: indirect spatial reference

ISO 19112 (Reference by geographical identifiers)

Properties:

- weakly-defined metric
- indirect reference system
- low, variable accuracy
- 1-dimensional search criteria

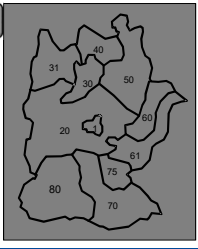
Addresses

Telephone book	
Glock Manfred	244 72 10
Isegrimweg 25	
Glock Udo	659 10 25
Fildeweg 29	
Glocke Eckhard	493 27 11
Heuweg 9a	
Glockenbring G.	264 54 55
Schellberg 7	
Glockner H.	62 66 23
Einsteinstr. 29	
...	


Site names

Ecuador
Quito
Rostock
Andes

Code numbers



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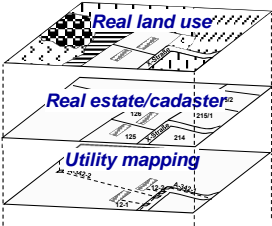
Spatial references – the important link

- Around 80% of all branch-specific administrative, logistic, and strategic activities in an enterprise or governmental organisation have a spatial reference

Geo-Information System

.....

Real land use



Real estate/cadaster

Utility mapping

Reports

UNIVERSITÄT ROSTOCK
Umfeldbericht
Ort: Störing-Werke, 3473
Beteiligte: Fahrzeug-HRD 3452 und AC 434


Files

- Haus Nr. 1 - 27
- Haus Nr. 1 - 25
- Haus Nr. 1 - 24
- Haus Nr. 1 - 23
- Grundstücke - 12353
- Anlagenort - Aachen
- Fläche - 154,2 m²


Tables

Grundstückskennung	Fläche
Rostock	400,43
Bül	1255,43


.....




Engineering and planning



Administration and government




Utility and services



Decision makers and citizens


.....

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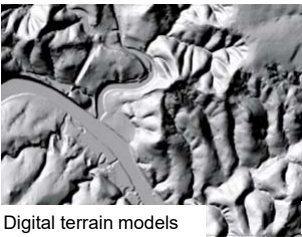


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Data in a GIS



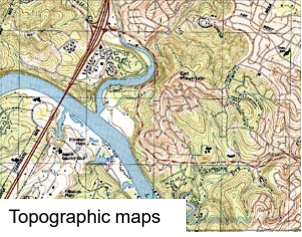
Contour lines



Digital terrain models



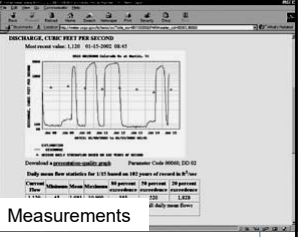
Satellite imagery



Topographic maps

stadtbereich.code	stadtbereich.bezeichnung	anzahl	g.f.
0	Wüstow	257	
1	Hakenwerder	259	
2	Gartenstadt-Stadtweide	190	
3	Rhododendro	33	
4	Warnemünde	125	
5	Dierkow-West	23	
6	Evershagen	447	
7	Südestadt	279	
8	Rhododendro	33	
9	Lütten Kien	362	
10	Brickmannsdorf	213	
11	Schneid	299	
12	Tollenwinkel	425	
13	Stadthörn	672	
14	Bielstow	50	
15	Reuterhagen	380	
16	Gehlsdorf	148	
17	Forst Kien	364	
18	Wüstow	22	
19	pehliner-Tor-Vorstadt	468	
20	Stenbagen	359	


Census data



Measurements

Source: http://erg.usgs.gov/isb/pubs/gis_poster/





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Data types in GIS: Geometrical data

- Geometrical elements are **points, lines and polygons** in vector form, pixels in raster form.
- They are defined in a **coordinate reference system** and describe the **shape and position of objects**.
- They may occur in analogue and/or digital, vector and/or raster form.
- **Coordinates** carry the geometric information.
- **Mathematical basis:** Computational geometry

Element	Vector		Raster	
	Digital	Analogue	Digital	Analogue
Point	x,y-coord.	•	Pixels	
Line	x,y-coord.-sequence	/	Pixels	
Polygon	closed x y coord.-sequence		Pixels	

Properties :


Vector data

- according to object lines
- logical structure
- well-known methods of acquisition
- small amount of data

Raster data

- according to position
- limited logical structure
- simple data acquisition
- large amount of data

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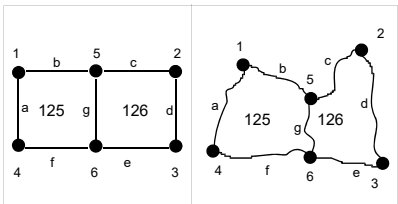


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Data types in GIS: Topological data

- Topological elements are **nodes (0-cells), edges (1-cells) and meshes (2-cells)**.
- Describe geometry without coordinates (so-called **neighbourhood relations**) and are invariant towards topologic transformations.
- The **edge** carries the topological information.
- **Mathematical basis:** Topology, Graph theory

Geometrically not equal
.. but ..
Topologically equal



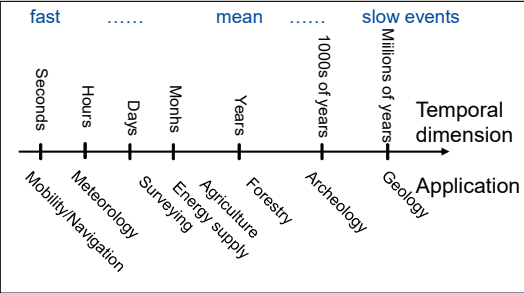
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Data types in GIS: Time and dynamics

- defines temporal reference system.
- Feature as an event within a certain interval.
- Feature has a time stamp.
- **Mathematical basis:** Time series analysis



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Data types in GIS: Attributes


- Attributes, descriptive data, special data.
- Name all non-geometric elements such as text, numbers, measurements etc.
- Are captured in a special context to solve special problems.
- Occur in analogue form as well as digital.
- **Mathematical basis:** Set theory, Relational algebra.

Analogue	Digital
Protocols	Data bases
Registers	Information systems
Notes	Files
..	..

Point number Street name Parcel number Grey values

128	A-street	128/1	64=field 64,126,32=forest
-----	----------	-------	------------------------------

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Data types in GIS: Graphical descriptions


- Graphic data = geometry data + graphical descriptions (styles)
- Graphical descriptions such as symbols, hatching, grey scales, line sizes, polygon fill etc.
- Basis: **Cartography, Visualisation**

Object repres.	Attribute-type	Fill type	Line type	Symbol type		
Attribute type:	Font	Height	Width	Orient.	Distanc.	Direction
Fill type:	Pattern	Border line	Area fill	Scale		
Line type:	Type	Repeating symbols	Parallel Lines	Color	Scale	
Symbol type:	Primitives	Masking	Origin	Scale		



- are found in analogue form (e.g. map) and digital form (e.g. screen graphic).
- usually have additional text elements in order to match standard graphic elements.

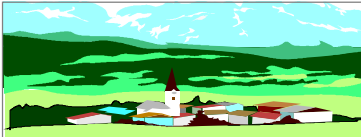
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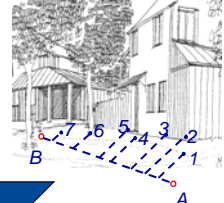
From real world to geoinformation processing


Landscape
Real world




Model
Capture
Process

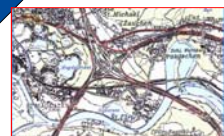


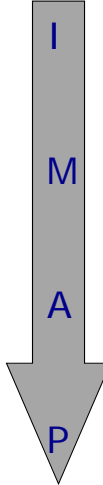





Visualise







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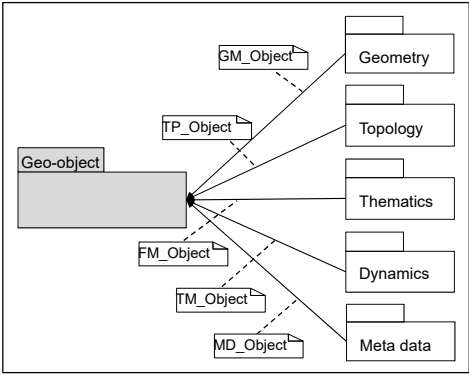


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Geo-object / spatial feature

- has
 - geometrical properties
 - topological properties
 - thematical properties
 - temporal properties.
- is described by meta information.
- has an object identifier (key).
- belongs to a feature class.



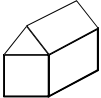
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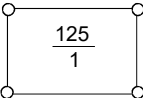
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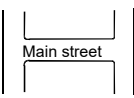
Basic object classes and spatial relations



Buildings
Coordinates
Street, House No.
Real Estate No.
(Re.-No.)

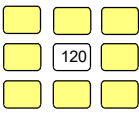


Parcels
Coordinates
Street, House no.
Re.-No.




Streets
Coordinates
Street Name
Street type


....



Building Blocks
Coordinates
Street Names
Block No.




Quarters
Coordinates
Name

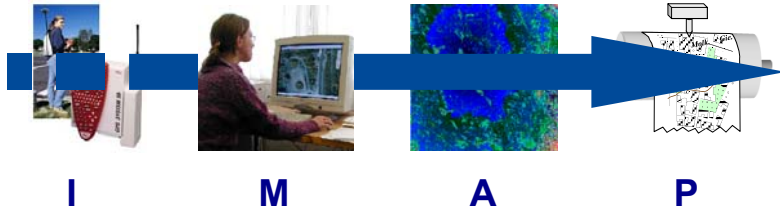


City
Coordinates
Name

....

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I M A P

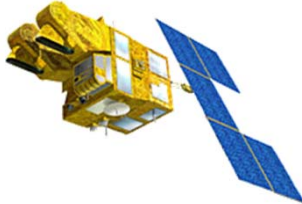

IMAP – THE PROCESSING CHAIN IN A GIS

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Input / capture of information in GIS

- Getting the data/information into the system by:
 - Geodetic methods
 - Photogrammetric methods
 - Remote sensing
 - Digitising/scanning
 - Attribute data collection
 - Integrating existing digital information
 - ... and
- defining their spatial reference system.

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SDG: Integrating existing digital information


un sustainable development goals data download

Global SDG Indicators Database - UNSO

Indicator 7.2.1, Series: Renewable energy share in the total final energy consumption (%) EG_FEC_RNEW

Country	Units	2005	2006	2007	2008	2009	2010	2011
Afghanistan	PERCENT	40.86 ¹	37.14 ¹	33.86 ¹	21.34 ¹	17.81 ¹	14.84 ¹	11.48 ¹
Albania	PERCENT	36.87 ¹	31.71 ¹	32.10 ¹	25.91 ¹	37.22 ¹	37.13 ¹	35.96 ¹
Algeria	PERCENT	0.04 ¹	0.41 ¹	0.41 ¹	0.20 ¹	0.31 ¹	0.24 ¹	0.18 ¹
Armenia	PERCENT	0.00 ¹	0.00 ¹	0.00 ¹	0.00 ¹	0.00 ¹	0.00 ¹	0.00 ¹
Andorra	PERCENT	16.90 ¹	17.49 ¹	16.94 ¹	17.42 ¹	17.32 ¹	18.09 ¹	18.97 ¹
Angola	PERCENT	70.93 ¹	65.02 ¹	61.60 ¹	58.11 ¹	55.75 ¹	54.19 ¹	52.72 ¹
Anguilla	PERCENT	0.14 ¹	0.12 ¹	0.12 ¹	0.12 ¹	0.12 ¹	0.12 ¹	0.12 ¹

alearthdata.com/downloads/50m-cultural-vectors/



1:50m Cultural Vectors

Download all 50m cultural themes (7.59 MB) version 4.1.0

Files have been downloaded 273,533 times.

NOTE: Version number indicates the update cycle when that theme was last updated. An older version number indicates updates have not been necessary since then.


Admin 0 - Countries

There are 247 countries in the world. Greenland as separate from Denmark. Most users will want this file instead of sovereign states.

Download countries (756.04 KB) version 4.1.0

Download without boundary lakes (772.6 KB) version 4.1.0

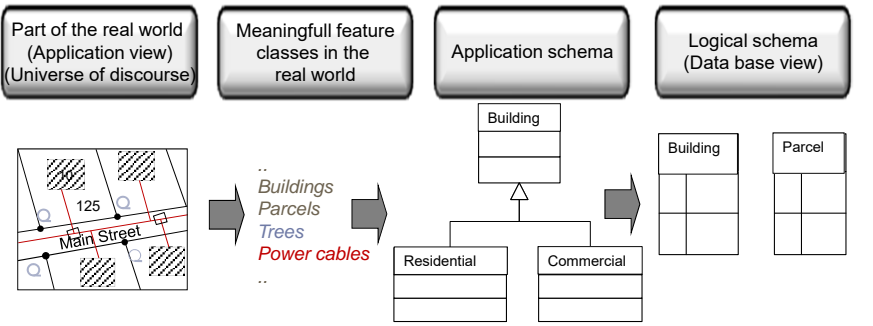
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Management of information in GIS

- Data models
 - Modeling languages
 - Relational data models
 - Object-Oriented modelling
- Data bases/information systems
 - Relational/object-relational DBs



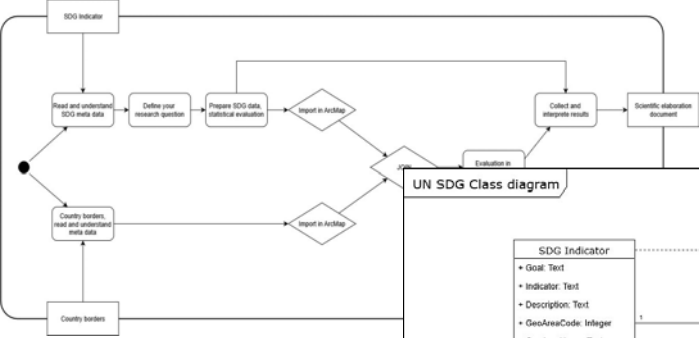
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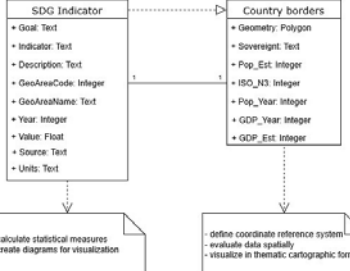
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SDG: Modeling the real world


- UML activity diagram (Process)
- UML class diagram (Data)



UN SDG Class diagram



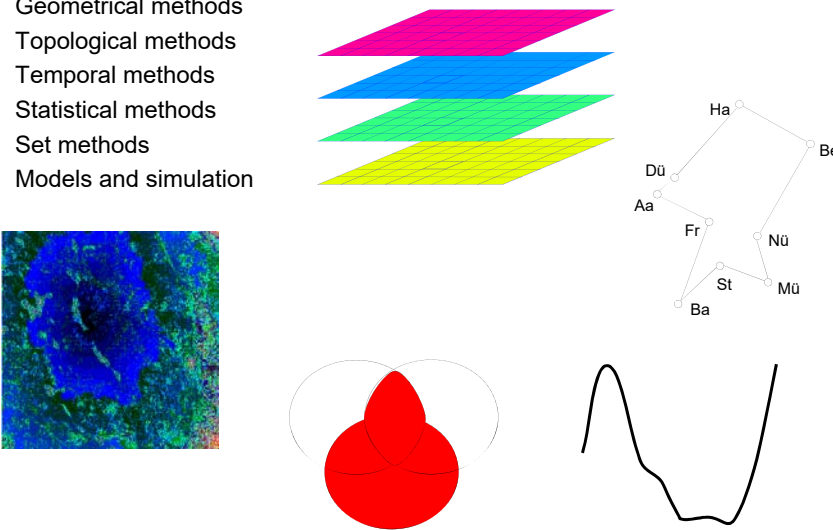
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Analysis of information in GIS

- Geometrical methods
- Topological methods
- Temporal methods
- Statistical methods
- Set methods
- Models and simulation



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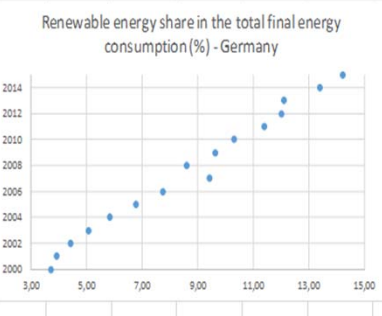


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SDG: Join & Temporal statistics


AreaCode	GeoAreaName	Value 2005	Value 2015
1	World	16,5	17,46
4	Afghanistan	40,86	16,42
8	Albania	36,67	38,62
9	Oceania	11,78	13,51
12	Algeria	0,58	
15	Northern Africa	13,78	
16	American Samoa	0	3,70 2000
20	Andorra	16,9	3,90 2001
21	Northern America	7,64	4,41 2002
24	Angola	70,95	5,06 2003
28	Antigua and Barbuda	0	5,83 2004
30	Eastern Asia	14,05	6,76 2005
31	Azerbaijan	3,37	7,75 2006
32	Argentina	8,96	
34	Southern Asia	39,29	9,41 2007
35	South-Eastern Asia	33,62	8,59 2008
36	Australia	6,71	9,63 2009
40	Austria	24,17	
44	Bahamas	1,84	10,29 2010
48	Bahrain	0	11,39 2011
50	Bangladesh	50,78	12,02 2012
51	Armenia	6,48	12,09 2013
			13,38 2014
			14,21 2015

SOVEREIGNT	TYPE	NAME	ISO_3166
Afghanistan	Sovereign country	Afghanistan	004
Albania	Sovereign country	Albania	008
Antarctica	Indeterminate	Antarctica	010
Algeria	Sovereign country	Algeria	012



Renewable energy share in the total final energy consumption (%) - Germany

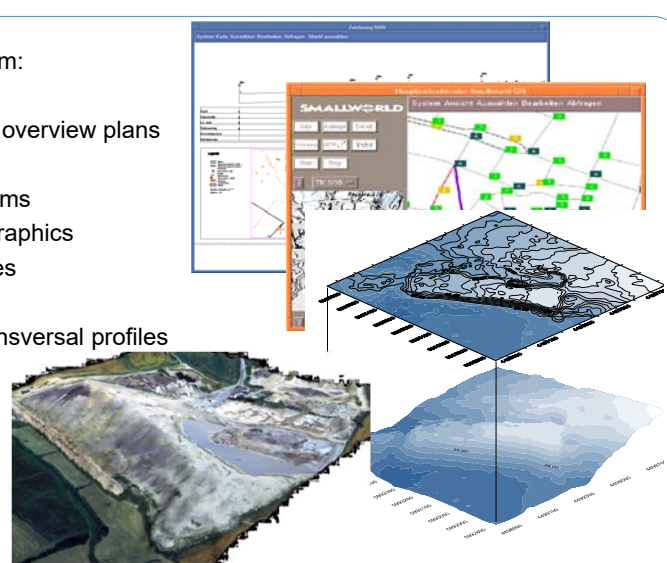
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Presentation / visualisation of information in GIS

- In analogue form:
 - Maps
 - Detail- and overview plans
 - Sketches
 - Map diagrams
 - Business graphics
 - Perspectives
 - Imagery
 - Length-/transversal profiles
 - Reports
 - Statistics
 - Tables
 - Others



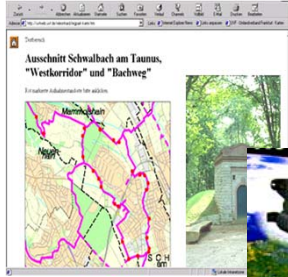

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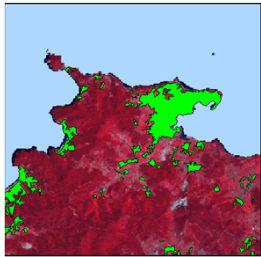



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Presentation / visualisation of information in GIS

- In electronic/digital form:
 - Interactive on screen
 - Multimedia
 - Fly through
 - Virtual- or Augmented Reality
 - Animation
 - Digital data exchange
 - Others





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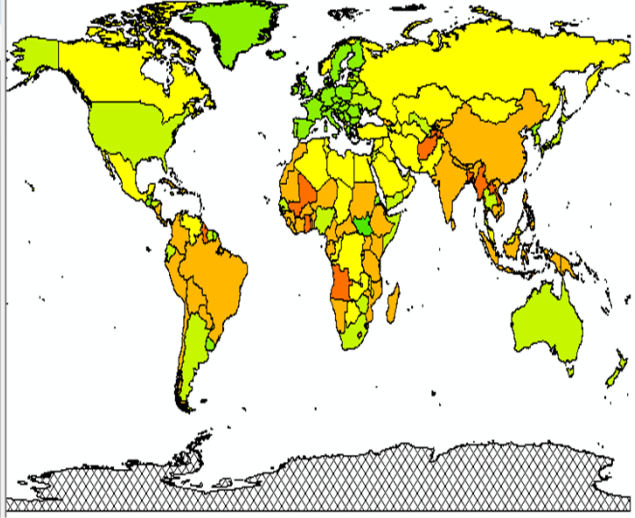
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SDG: Visualising the results

Table Of Contents	
Layers	
<ul style="list-style-type: none"> [-] R:\Profile\Personal\UN_SDG_U [-] World_Countries_General 2005_2015 <input checked="" type="checkbox"/> No Data <input type="checkbox"/> -29 - -16 <input type="checkbox"/> -15 - -3 <input type="checkbox"/> -2 - 0 <input type="checkbox"/> 1 - 3 <input type="checkbox"/> 4 - 22 <input type="checkbox"/> 23 - 63 	
<ul style="list-style-type: none"> [-] R:\Profile\Personal\UN_SDG_U <input type="checkbox"/> UN_SDG_Energy.csv 	

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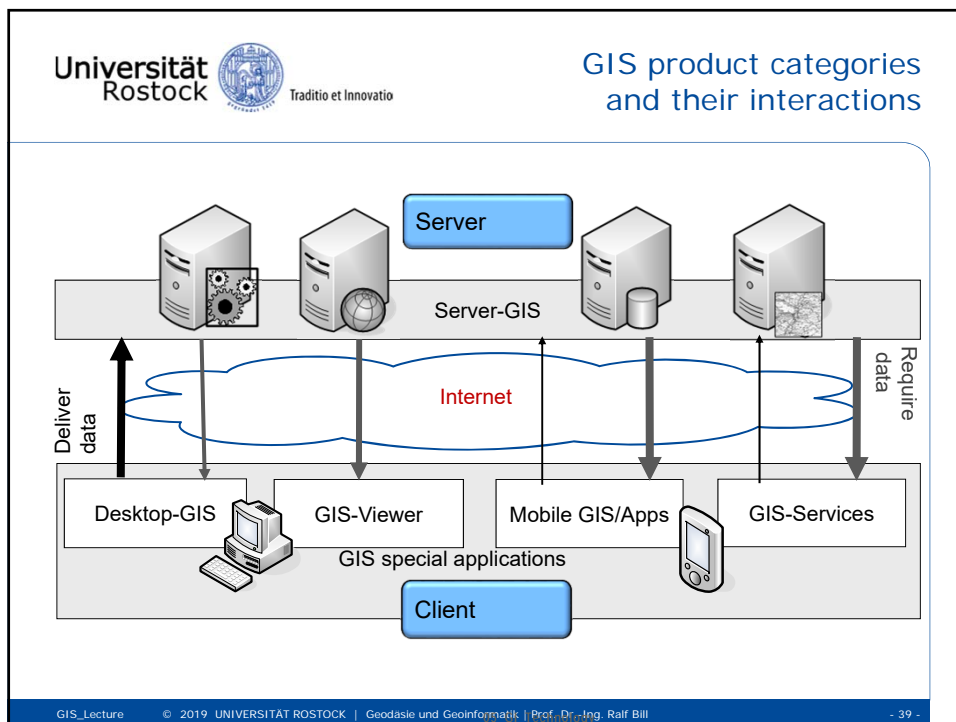
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ADVANCED TECHNOLOGIES


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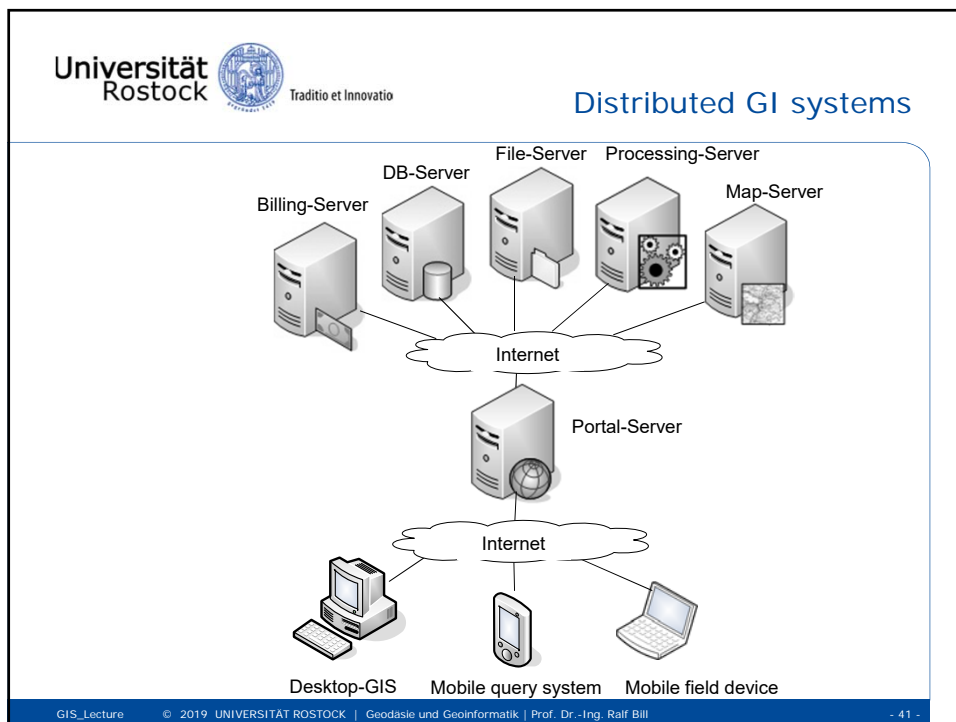
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GIS desktop products

- Commercial products:
 - ESRI ArcGIS
 - Autodesk AutoCad Map 3D
 - Smallworld
 -
- Open Source products:
 - Quantum GIS
 - Geographic Resources Analysis Support System (GRASS)
 - OpenJUMP



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Standardisation

- de-jure ⇔ de-facto
- Formal ⇔ technical






- Products: Paperware
- Goal: Formalisation and Interoperability




Open Geospatial Consortium Inc.
Date: 2009-03-15
Reference number of this document: OGC09-05-042
Version: 1.3.0
Creator: OpenGIS® Implementation Specification
Editor: Jeff de la Beauportiere

OpenGIS® Web Map Server Implementation Specification

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To obtain additional rights of use, visit <http://www.opengeospatial.org/ogc/>

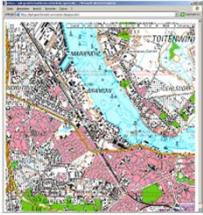
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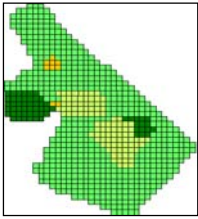
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Open Geospatial Consortium: Web Services

- **OGC Web Map Service (WMS)**
 - Access to raster maps/imagery (GIF/PNG/JPG)
- **OGC Web Feature Service (WFS)**
 - Access to features/vector data (GML)
- **OGC Web Coverage Service (WCS)**
 - Access to raster coverages
- and many others








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National Mapping in Ecuador
Institute Geographico Militar

- Geoportal of IGM



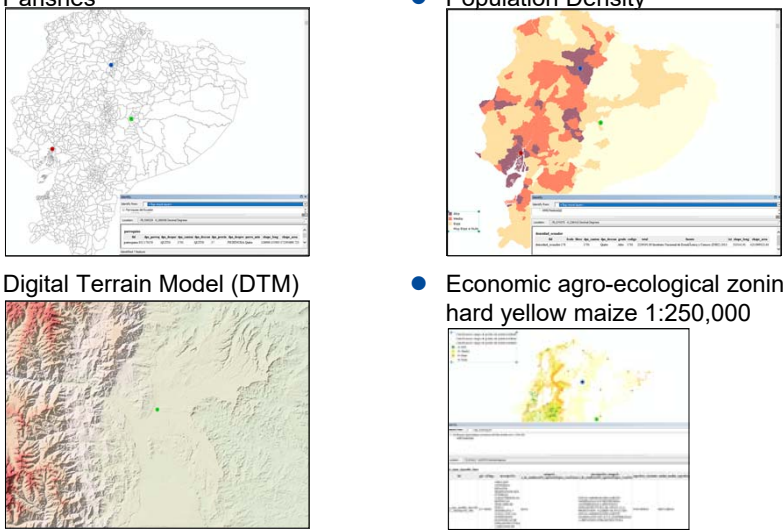
<http://www.geoportaligm.gob.ec/portal/index.php/visualizador/>

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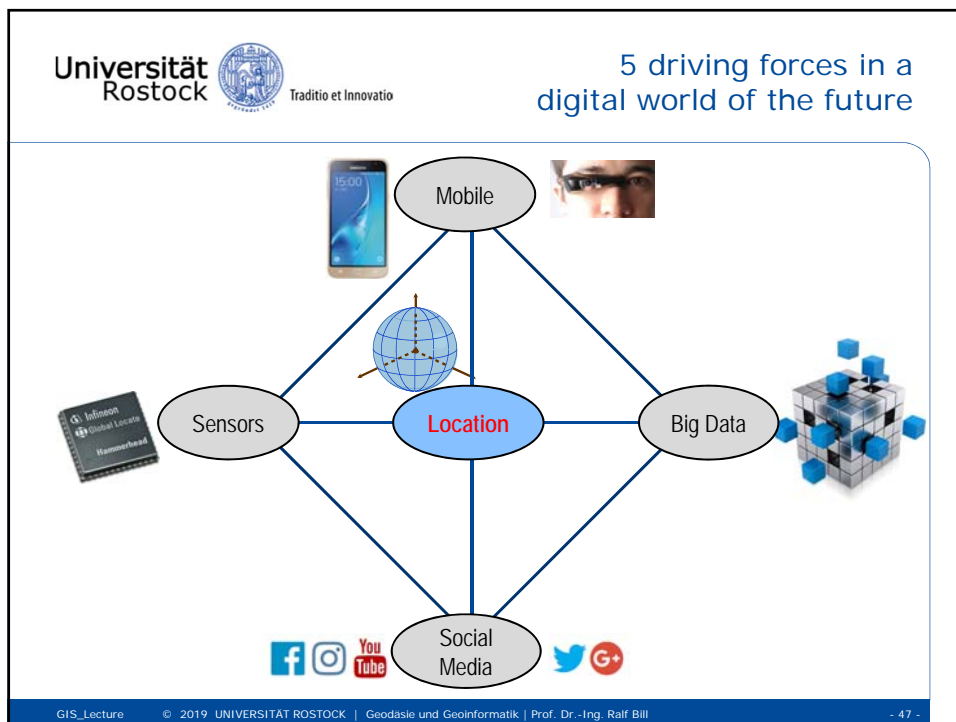
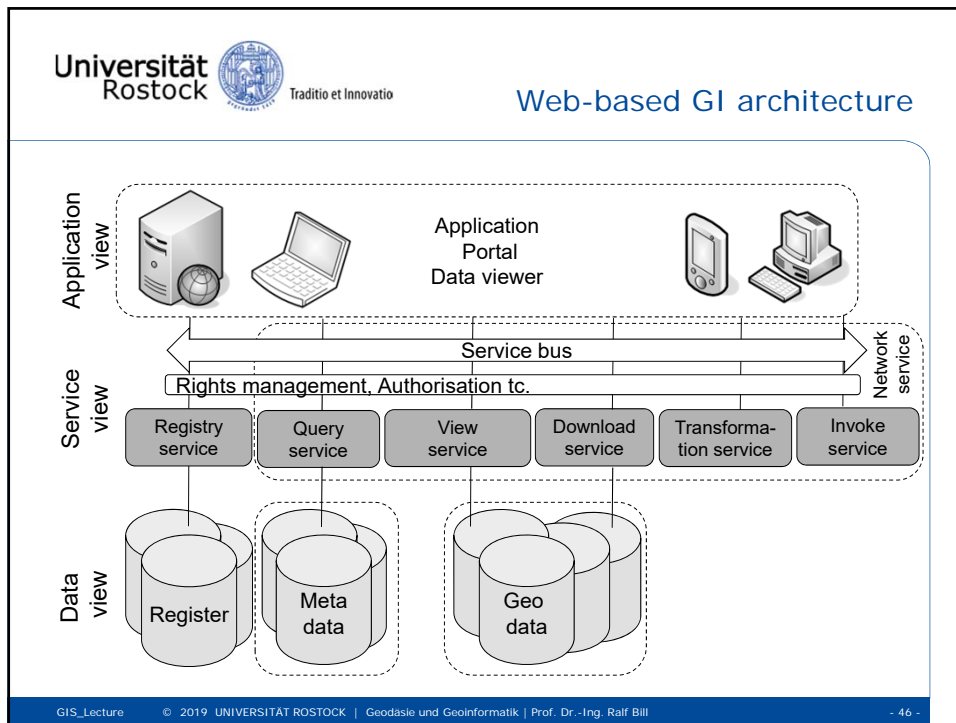
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Examples:
WMS Ecuador

- Parishes
- Population Density
- Digital Terrain Model (DTM)
- Economic agro-ecological zoning of hard yellow maize 1:250,000



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Sensors – new ways of data acquisition









Photo: Hitachi

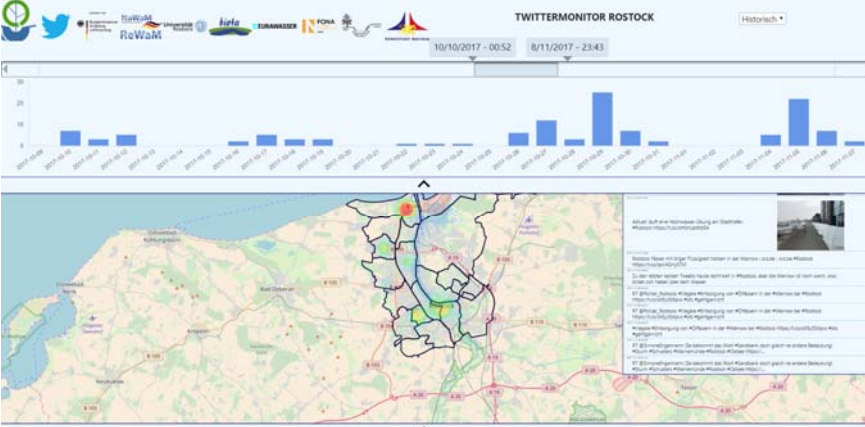
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Social media

- Twitter monitor Rostock



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Mobile

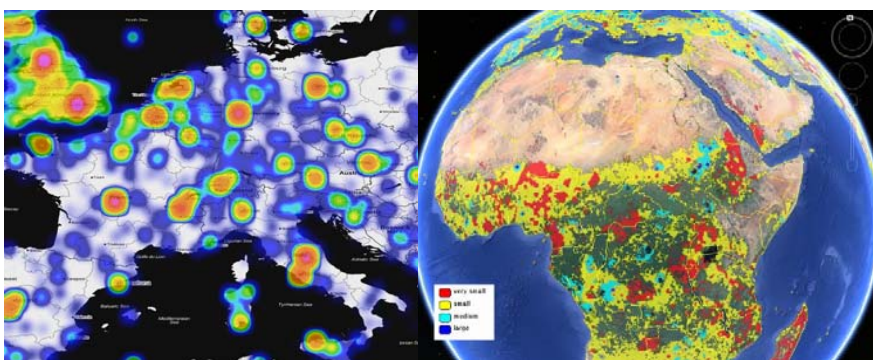
- Our mobile devices (Smartphone/Tablet) will become classical user interfaces to GIS.



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Big data



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APPLICATIONS

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Mapping

The screenshot displays a GIS interface with a map showing a grid of land parcels. Several parcels are highlighted with red polygons. A legend on the right side of the map lists various layers and their corresponding symbols. The legend includes items such as 'Flurkarte', 'Flurkarte_01', 'Flurkarte_02', 'Flurkarte_03', 'Flurkarte_04', 'Flurkarte_05', 'Flurkarte_06', 'Flurkarte_07', 'Flurkarte_08', 'Flurkarte_09', 'Flurkarte_10', 'Flurkarte_11', 'Flurkarte_12', 'Flurkarte_13', 'Flurkarte_14', 'Flurkarte_15', 'Flurkarte_16', 'Flurkarte_17', 'Flurkarte_18', 'Flurkarte_19', 'Flurkarte_20', 'Flurkarte_21', 'Flurkarte_22', 'Flurkarte_23', 'Flurkarte_24', 'Flurkarte_25', 'Flurkarte_26', 'Flurkarte_27', 'Flurkarte_28', 'Flurkarte_29', 'Flurkarte_30', 'Flurkarte_31', 'Flurkarte_32', 'Flurkarte_33', 'Flurkarte_34', 'Flurkarte_35', 'Flurkarte_36', 'Flurkarte_37', 'Flurkarte_38', 'Flurkarte_39', 'Flurkarte_40', 'Flurkarte_41', 'Flurkarte_42', 'Flurkarte_43', 'Flurkarte_44', 'Flurkarte_45', 'Flurkarte_46', 'Flurkarte_47', 'Flurkarte_48', 'Flurkarte_49', 'Flurkarte_50', 'Flurkarte_51', 'Flurkarte_52', 'Flurkarte_53', 'Flurkarte_54', 'Flurkarte_55', 'Flurkarte_56', 'Flurkarte_57', 'Flurkarte_58', 'Flurkarte_59', 'Flurkarte_60', 'Flurkarte_61', 'Flurkarte_62', 'Flurkarte_63', 'Flurkarte_64', 'Flurkarte_65', 'Flurkarte_66', 'Flurkarte_67', 'Flurkarte_68', 'Flurkarte_69', 'Flurkarte_70', 'Flurkarte_71', 'Flurkarte_72', 'Flurkarte_73', 'Flurkarte_74', 'Flurkarte_75', 'Flurkarte_76', 'Flurkarte_77', 'Flurkarte_78', 'Flurkarte_79', 'Flurkarte_80', 'Flurkarte_81', 'Flurkarte_82', 'Flurkarte_83', 'Flurkarte_84', 'Flurkarte_85', 'Flurkarte_86', 'Flurkarte_87', 'Flurkarte_88', 'Flurkarte_89', 'Flurkarte_90', 'Flurkarte_91', 'Flurkarte_92', 'Flurkarte_93', 'Flurkarte_94', 'Flurkarte_95', 'Flurkarte_96', 'Flurkarte_97', 'Flurkarte_98', 'Flurkarte_99', 'Flurkarte_100'. The map also includes a scale bar and a north arrow.


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Planning



Zoning plan City of Rostock



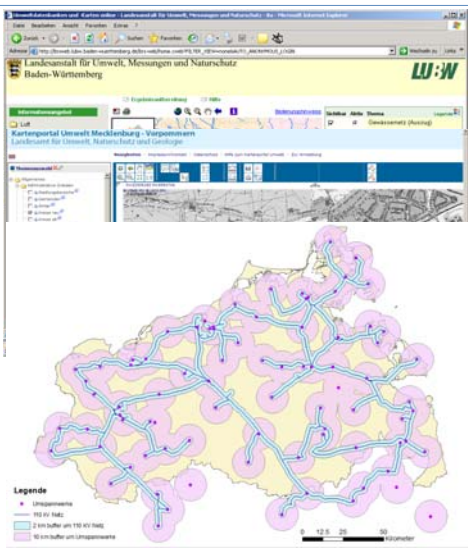


Detailed plan: www.pirmasens-land.de

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Environmental information systems

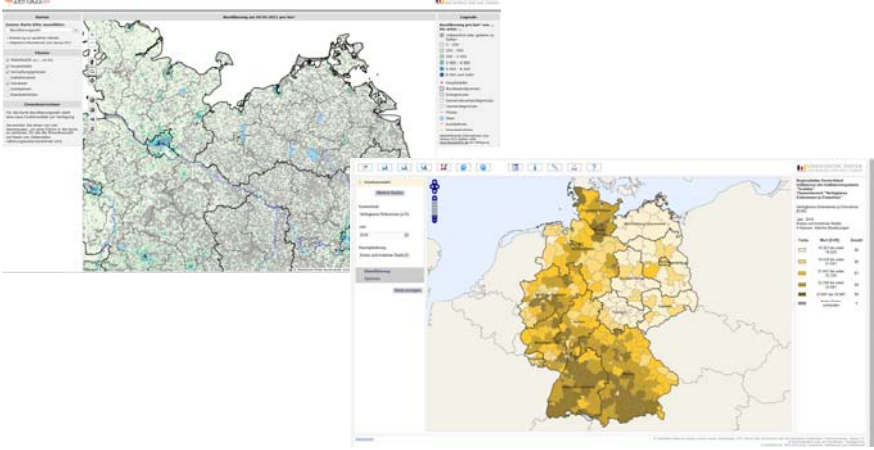


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Statistical information

- Census 2011: Population density/km²
- Regional atlas: Available income per inhabitant



Source: <https://www.regionalstatistik.de/genesis/online/> or <https://www.statistikportal.de/> (23.04.2018)

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Utility companies



Management of supply networks


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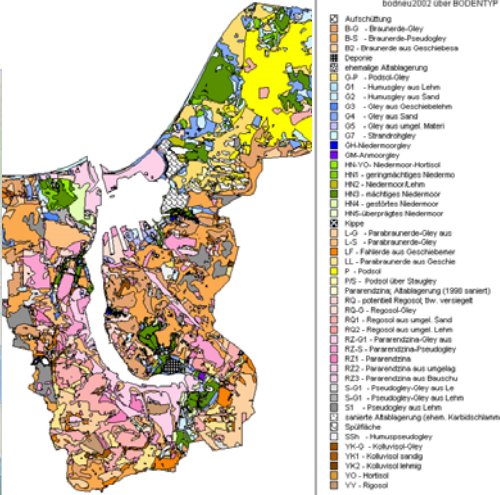
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Agriculture - Soil information

- Soil loss by water erosion in EU
- Soil type mapping in Rostock




Soil loss rates
t/ha per year



bodneu2002 über BODENTYP

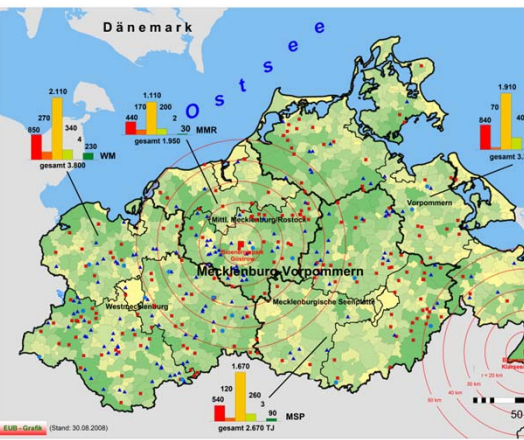
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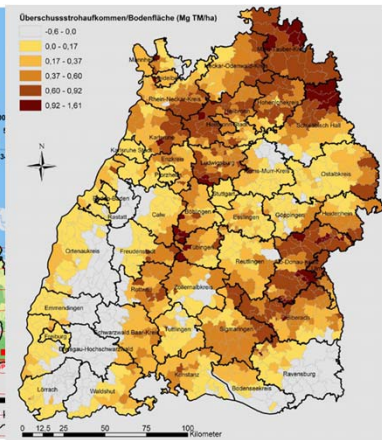
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Agriculture - Renewable energies

- Power production from biomass
- Energy production from organic waste




Dänemark
Ostsee
Meklenburg-Vorpommern
Westpommern
Mecklenburgische Seenplatte
Rostock
Vorpommern
MSP
WM
gesamt 2.670 Tj
gesamt 1.950
gesamt 3.300
gesamt 3.3



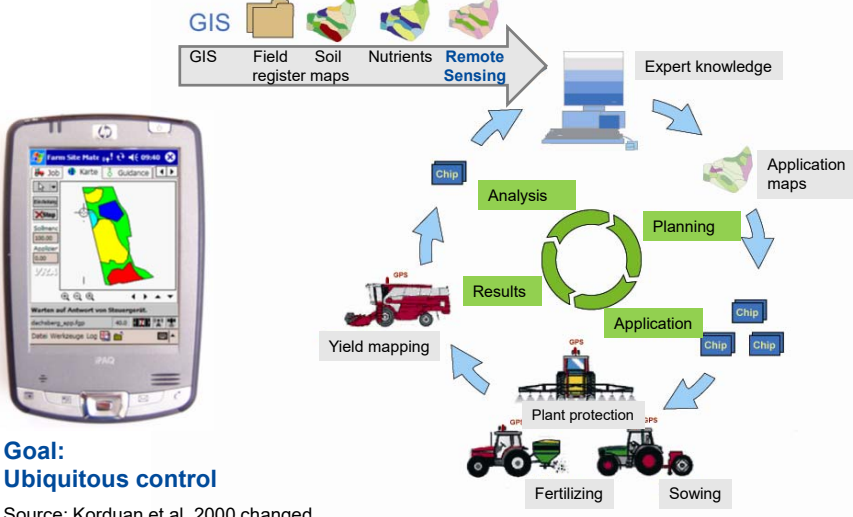
Überschussstrohaufkommen/Bodenfläche (Mg TM/ha)

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Agriculture – Precision Farming



Goal: Ubiquitous control

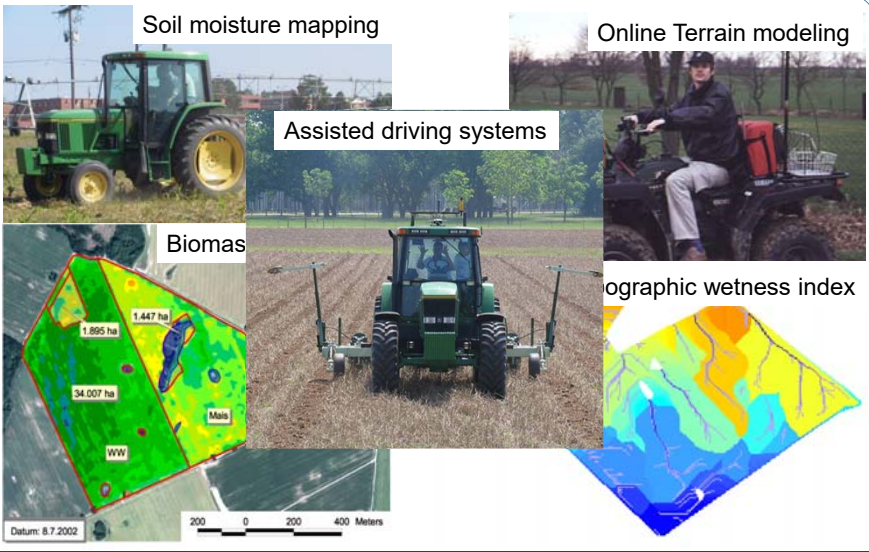
Source: Korduan et al. 2000 changed

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Agriculture – Precision Farming



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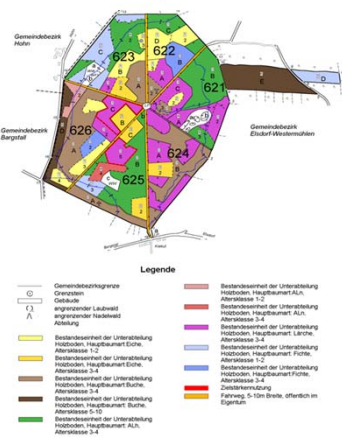


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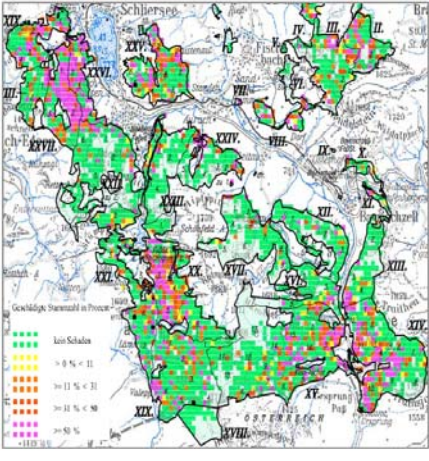
Forestry

Forest mapping

Thematik: Erstellen einer Forstkarte entsprechend der forstwirtschaftlichen Spezifik hinsichtlich Linien- und Flächengrößen mit dem GIS TRABIS



Forest inventory



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SUMMARY

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- is a computer-based system capable of holding and using **data describing places on the earth**.
- **links spatial data with context** about a particular feature on the earth.
- doesn't hold maps or pictures - it runs a **database**. The heart of any GIS is the database through which questions such as what a feature is, where it is, and how it relates to other features can be answered.
- gives you the ability to associate information with a feature on the earth and to **create new relationships** that can determine the suitability of various sites for development, evaluate environmental impact, identify the best location for a new facility, and so on.
- turns **data** into information and **information** into **knowledge** by spatial analysis.
- encourages **cooperation** and **communication** among different users.
- is an **analytical tool**. The major advantage of a GIS is that it allows you to **identify the spatial relationship between features on the earth**.
- stores the data from which you can **draw a desired view to suit a particular purpose**.