Existing Open Source Tools and Possibilities for Cadastre Systems

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Key words: Digital cadastre, Low cost technology, Open source software

SUMMARY

When it comes to computer software, the old saying "you get what you pay for" may no longer apply. After years of skepticism towards open source software, many of today's open source solutions are as good, if not better than proprietary software solutions. The question is- why is it then that there are so few land administration systems making use of open source software technology? Lack of knowledge about the possibilities might be one of the reasons. After all, marketing has never been a priority for developers of open source software. Doubts about the security and available software support could further shy away cadastre agencies from making the switch.

The FAO-FIG publication on *FLOSS in Cadastre and Land Registration – Opportunities and Risks* looks into these issues. Chapter 3, section 1 of the publication intends to give an overview of available open source database and GIS tools that are useful for cadastre systems. First, cadastre systems and their software requirements are analyzed, and then an overview is given of open source alternatives. The core of digital cadastre systems generally consists of a data repository containing cadastral boundaries and land register data. When comparing open source database products PostgreSQL and MySQL it is found that both are excellent database tools, but PostgreSQL with PostGIS has better spatial functionality than MySQL.

GIS software is needed for the manipulation and updating of cadastral map data. A review of a number of open source desktop GIS software products revealed that there have been major improvements in editing functionality recently. Multiple open source desktop GIS now support the cutting and merging of polygons, which are essential functions for the maintenance of cadastral parcel boundaries. The reviewed GIS products have the advantages of platform independency (they run on Linux, Windows and most of them also on MacOS) and interoperability through the compliance with open standards, direct database connections to PostgreSQL and/or MySQL, good topology validation tools, and multiple interface translations which makes these products especially useful in non-Anglophone countries.

This paper, which is an extract of the 3rd chapter, 1st section of the FAO-FIG publication, is an attempt to raise awareness on the potential of open source software for cadastre systems. The use of open source software for building sustainable systems makes a lot of sense. Open source solutions are more flexible and adaptable to local conditions and languages than proprietary software. By using and improving open source software, cadastres can build local knowledge and contribute to the development of open source projects that can in turn benefit other cadastres world-wide.

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1. INTRODUCTION

What we call cadastre today comes from a long history of keeping maps and descriptions of land boundaries, together with written records on land ownership. Although the organization of cadastre and land registration operations will vary from one country to another, cadastral and land registry offices usually handle administrative and technical tasks to document and maintain information on land property. The FIG statement on Cadastre (FIG, 1995) defines cadastre as follows:

A cadastre is normally a parcel based, and up-to-date land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, the ownership or control of those interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes, legal purposes, or to assist in the management of land and land use and enables sustainable development and environmental protection.

Even though there is a strong relationship between cadastre and land registration functions, they differ in content. While the land register holds the records on right on land through deeds or titles, the cadastre contains information about land properties and their boundaries within a certain administrative area. Land registration and cadastre functions complement each other and should ideally be handled within the same system. The second statement of the Cadastre 2014 model (Kaufmann and Steudler, 1998) foresees an abolishment of the separation between cadastral maps and land registers. Yet in many cases, they are functioning independently in separate organizations and not always co-operating in the most efficient way (Zevenbergen, 2004).

The design of digital cadastral systems must take the organization and required distribution of information into account. While new technologies allow data to be stored centrally, the cadastre and land registration functions might be implemented at local level with little cooperation between administrative areas within the same country. Or the land register might be maintained at central level, while cadastral offices maintain the graphic information locally. Many countries have an incomplete coverage, i.e. only the most populated part of the country is registered while land in more remote areas is not registered at all. Some countries organize systematic registration with the objective to achieve complete coverage of cadastral registration. For other countries this is considered too expensive and land parcels might be included when ownership transfer takes place, or on demand through sporadic registration.

Whether the information is stored centrally or decentralized in lower administrative levels, the extent of cadastral coverage (or number of registered parcels), and the way in which cadastral information is accessed and updated, all these are considerations with a direct impact on the design of the cadastral system architecture and the choice of software. A digital cadastral system that is being built up from scratch in a small pilot region of a developing country will initially require simple tools and low-cost solutions that can be extended and upgraded later on. Centralized cadastres with online information services covering large administrative areas need sophisticated, scalable systems. What all cadastre systems have in common is the need for a spatial data store to keep and maintain cadastral data, and graphical editing tools to create and update cadastral boundaries. In different economic settings, open source software can play a role.

2. DIGITAL CADASTRE SYSTEMS

In theory, a digital cadastre system consists of three basic software components as presented in Fig. 1. The core of the system, represented in red, is the data repository which stores the cadastral data. Alphanumeric data is usually stored in relational Database Management Systems (RDBMS). To be able to store and maintain spatial data, RDBMS are extended with spatial data engines.

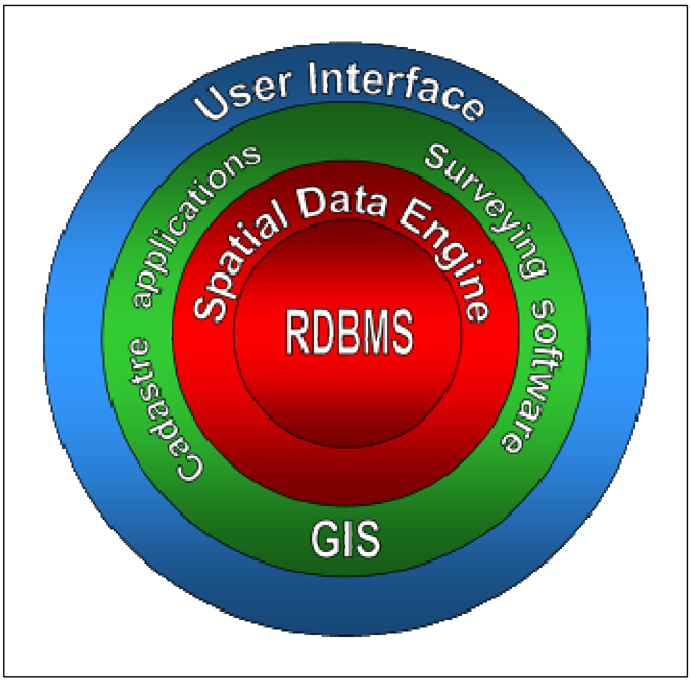

Fig. 1 Software components of cadastre and land registration systems

The green part of the diagram represents the mapping functionality, which may include a combination of GIS and surveying software with cadastre applications. The user interface is the outer layer, the visible part of the system through which users interact with the software and data. In reality, digital cadastre systems may have multiple user interfaces for different functions and different groups of users. For example, there might be an interface for cadastral officers to record transactions, an interface through which banks can access information on mortgages, and an online information service for public enquiries. When comparing cadastre and land registration systems from one country to another, the user interfaces will have little in common and reflect local implementation of land administration regulations.

3. DATABASE SOFTWARE

The data repository, the core of any digital cadastre system, holds the cadastral boundaries and textual land registration data. It is very important that the data storage is reliable and safe. RDBMS software is used to manage large amounts of data while restricting unauthorized access to the information. For cadastre systems, RDBMS software that can handle spatial data is needed. Oracle Spatial is probably the most popular spatial database software used in cadastre systems, but open source alternatives exist. When comparing open source database software products with spatial capabilities, there are basically two options. MySQL includes native support for spatial functions, while PostgreSQL can be extended with PostGIS to handle spatial operations.

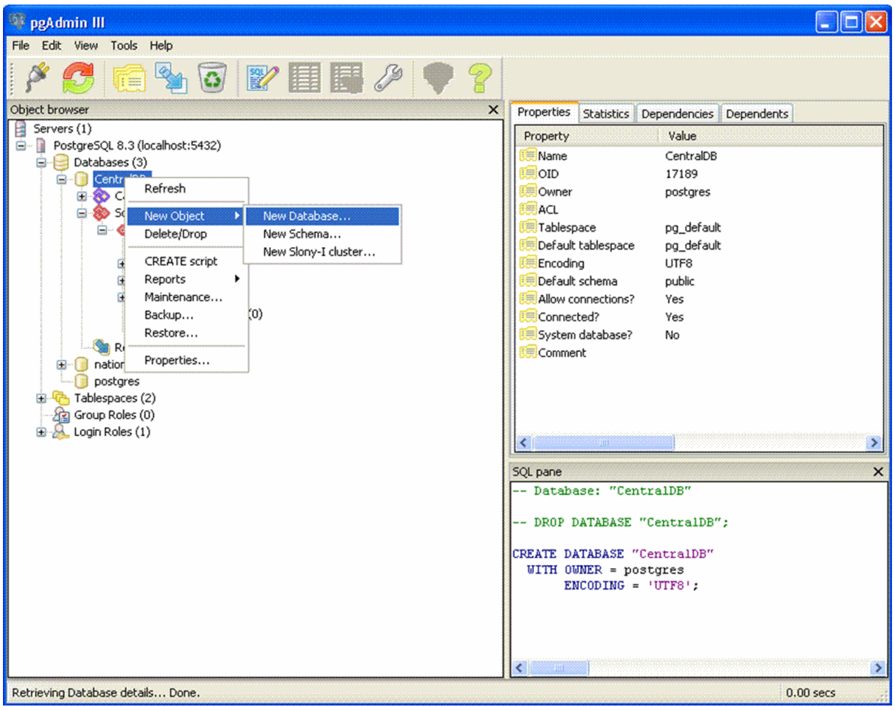

Fig. 2 The PgAdmin GUI lets users easily create and maintain PostgreSQL databases

Both MySQL and PostgreSQL are reliable database products and gaining in popularity, but when it comes to geometry and topology support, PostgreSQL with PostGIS offers more functionality than MySQL. One of the strengths of PostgreSQL/PostGIS is that it has become the standard spatial database for all open source GIS tools (Ramsey, 2007).

PostgreSQL can be installed on a number of different operating systems, including Linux and Windows. After downloading the installation file, the actual installation only takes a few mouse clicks and less than a minute of time. The Windows installer comes with PgAdmin, a graphic user interface (GUI) for PostgreSQL and guides the users through the installation of

PostGIS as well. The PgAdmin interface does not take long to get used to, and users can easily start to create databases, add tables and columns. Although the design and maintenance of PostgreSQL databases does require database expertise and knowledge of Standard Query Language (SQL), PostgreSQL is certainly not more complicated than Oracle or SQL Server to install and use.

4. DESKTOP GIS SOFTWARE

Open source GIS software has really taken off during the last few years and there is now a full range of desktop GIS products available that are potentially useful for cadastre systems. New versions are coming out regularly and there have been major improvements in vector editing, database connections and spatial operations. The subdivision and merging of polygons, which is so important to maintain parcel boundaries in cadastre systems, is now supported in Quantum GIS, uDIG, gvSIG, OpenJump and Kosmo GIS. More and more desktop GIS products (proprietary as well as open source) are adopting the Open Geospatial Consortium (OGC) interoperability standards to access remote geographic datasets over the internet. With Web Map Service (WMS) support, datasets from web mapping servers can be displayed as images, while the Web Feature Service (WFS) gives users access to the raw geographic datasets. While few cadastre authorities distribute cadastre datasets through WFS as yet, this technology is expected to gain popularity in the coming years.

Vector editing functions to create and maintain parcel polygons, topology validation, database connections and support for common vector and raster data formats are considered essential characteristics of GIS desktop software for cadastre systems. These and other characteristics are compared for GRASS, Quantum GIS, uDIG, gvSIG, Open JUMP and Kosmo in the table below. GRASS, which was the first and probably the best known open source GIS tool, can now also be installed on Windows systems. Quantum GIS is a light-weight frontend for GRASS data which works also well with PostGIS data. uDIG, gvSIG, OpenJUMP and Kosmo are Java based desktop GIS products, each with its own strengths and characteristics. Of all the compared products, uDIG is the first software that fully supports transactional WFS (WFS-T), which means that with uDIG, edits can be made to remote WFS datasets. WFS-T connectors for gvSIG and Kosmo are under development. gvSIG is a very useful GIS product with extensive vector editing functions. A mobile version of gvSIG is being developed which can connect to GPS receivers and generate tracks and waypoints. Both OpenJUMP and Kosmo have good topology validation tools and vector editing functions. OpenJUMP has recently been integrated with Sextante (also used by gvSIG and Kosmo), which adds extensive raster analysis tools to the software. Kosmo is derived from OpenJUMP, and has improved the database connections and performance, which makes it more suitable to work with large datasets. Undoubtedly, there are other useful open source GIS products that have not been mentioned here. Yet, the compared products are considered the most useful desktop GIS products in cadastre systems.

Table 1 FLOSS Desktop GIS products compared

PROPERTIES	GRASS 6.4	Quantum GIS 1.3	uDIG 1.1.1	gvSIG 1.9	OpenJUMP 1.3	KOSMO 2.0
Type of product	Open source desktop GIS with raster, image processing and vector analysis functionality	Open source desktop GIS with vector and raster support, to browse and create map data	Open source internet oriented desktop GIS	Open source desktop GIS with CAD, vector and raster support	Open source desktop GIS for manipulating spatial features with geometry and attributes	Open source desktop GIS, derived from OpenJUMP
License	GNU/GPL	GNU/GPL	GNU/LGPL	GNU/GPL	GNU/GPL	GNU/GPL
Website	http://grass.osgeo.org	http://www.qgis.org	http://udig.refractions.net	http://www.gvsig.gva.es	http://www.openjump.org	http://www.opengis.es
Operating system	Linux, MacOSX and Windows	Linux, MacOSX and Windows	Linux, MacOSX, Windows	Linux, Windows, MacOSX	Unix, Linux, MacOSX, Windows	Linux, Windows
Supported vector formats	GRASS vector (native format), read directly Shapefile, PostGIS; can import TIGER, DGN, MapInfo and GML2	OGR formats (Shapefile, MapInfo MIF/TAB, ArcInfo Coverage, GML) PostGIS, GRASS	Shapefile, PostGIS, OGR vector formats, GML	Shapefile, dgn, dxf, dwg, PostGIS, WFS vector layers	JML (OpenJUMP GML) Shapefile, WKT Plugins for DXF, CSV, MIF, GeoConcept and PostGIS	Shapefile, dxf, dwg, csv, PostGIS
Vector creation	Point, line, boundary, centroid (v.edit module)	Point, line, polygon (also polygon with holes or islands)	Polygon, line, point, rectangle, ellipse (also polygon with holes), arc	Point, multipoint, Line, arc, polyline, polygon, rectangle, circle, ellipse	Point, line, polygon (also polygon with holes) rectangle, multiPoints, multiPolygon, multiLine	Point, Line, Polygon (also polygon with holes), rectangle, circle, arc
Cut and merge polygons	No	Yes	Yes (Axios editing tools)	Yes	Yes	Yes
Other editing functionality	Merge and break lines; copy/move/delete/ flip vector features; Dissolve polygons Trim/extend lines	Move line, split line (GRASS layers)	Clip, trim lines, dissolve (Axios editing tools)	Move, rotate or flip features, clip, dissolve	Move, rotate features, split lines	Extend / trim lines, draw parallel and perpendicular lines, rotate features, clip, dissolve
Buffer (around point, line or polygon)	Yes (v.buffer)	Yes	Yes	Yes	Yes	Yes
Vector Overlays (Union, Intersect, Subtraction)	Yes	Yes (v.overlay with GRASS toolbox)	Yes (Axios spatial operations)	Yes	Yes	Yes
Spatial queries on vector layers	Yes (v.distance)	No	Yes (Contains, crosses, disjoint, equals, intersects, overlaps, touches, within)	Yes (nearest neighbour / contained in)	Yes (intersects, contain, assign data by location)	Yes
Field calculator (perform calculations on the fields of a table)	No	No	No	Yes	No	Yes
Calculate area of polygons	Yes (v.to.db)	For GRASS layers (v.to.db)	No	Yes	Yes	Yes
Convert lines to polygons	No	No	No	Yes	Yes	Yes

PROPERTIES	GRASS 6.4	Quantum GIS 1.3	uDIG 1.1.1	gvSIG 1.9	OpenJUMP 1.3	KOSMO 2.0
Snapping tools	Snap function to snap one line to another while digitizing.	The software allows the user to set the snapping tolerance and snap to nodes and vertices	Snap radius can be set to snap to nodes and vertices.	The software allows users to set the snapping tolerance and snap to nodes and vertices. Snapping to elements from different layers is also possible.	Vertices can be snapped to the reference grid, as well as to other vertices or lines.	Snap tolerance can be set to snap to lines or vertices, or snap to a grid
Topology tools	Module v.build to build topology; v.clean to clean topology	Only for GRASS layers with the v.build GRASS module	With the validation plugin, vector layers can be checked for correct geometry, self-intersecting or overlapping lines and dangling nodes.	Topology extension to check and maintain correct topology	Topology validation tool to check for valid geometry	Topology validation tool to check for valid geometry
Raster support	More than 40 supported raster formats (through GDAL)	TIFF, ERDAS (.IMG) ArcInfo ASCII Grid SDTS (.ddf) DTED Elevation raster (.dt0) USGS DEM AIG GRASS	TIFF, JPG, GIF	TIFF, JPG, ECW, MRSID	TIFF, GIF, JPG, ECW and PNG	TIFF, PTIF, BMP, JPB, GIF, PNG, MRSID, ECW
Raster analysis	Yes	Yes (GRASS module)	Yes (JGRASS)	Yes (Sextante)	Yes (Sextante)	Yes (Sextante)
GPS tools	Import waypoints, routes, and tracks from a GPS receiver or GPS download file into a vector map (v.in.gpsbabel)	Supports GPX format, download from/ upload to GPS through GPSBabel	With the BeeGIS plugin, users can connect to GPS receivers, upload GPS data and convert to PostGIS or shapefile	gvSIG Mobile Pilot can connect to GPS receivers and generate tracks and waypoints in GPX format	SurveyOS plugin for importing survey data in OpenJUMP	No
Database / SDBMS support	PostGIS, MySQL, SQLite	PostGIS	PostGIS, Oracle Spatial, ArcSDE, DB2, and MySQL	PostGIS, MySQL, Oracle Spatial, ArcSDE	JUMP DB Query Plugin for PostGIS, MySQL, Oracle Spatial, ArcSDE	PostGIS, MySQL, Oracle Spatial
Programming language	ANSI C	C++	Java	Java	Java	Java
Development platform / class libraries	Software components depend on multiple libraries	Qt with PROJ4, GEOS, SQLite, GDAL/OGR and other libraries	Eclipse RCP with GeoTools libraries	Eclipse with GeoTools, JTS and other libraries	Java Topology Suite (JTS)	GeoTools, JTS
Command line / Menu bar	Both	Menu bar	Menu bar	Both	Menu bar	Menu bar
Interface language	Translated into 20 languages, more coming	Translated into 26 languages	English, German, Spanish, French, Italian	Valencian, Spanish, Galician, English, Czech, German, Basque, French, Italian, Portuguese, Chinese	English, Finnish, Portuguese, French, Italian, German, Spanish	English, Spanish, Basque, Catalan, Russian, German, Italian, Czech, Slovak, Brazilian Portuguese
GML	Yes	Yes	Yes	Yes	Yes	Yes
WMS	Yes (r.in.wms)	Yes	Yes	Yes	Yes	Yes
WFS	Yes (v.in.wfs)	Yes	Yes	Yes	Yes	Yes
WFS-T	No	No	Yes	Under development	No	Under development

5. SURVEYING TOOLS

Although the surveying software market is a specialized area dominated by commercial vendors, a number of open source developments are worth mentioning. The GNU Gama[1] project is dedicated to adjustment of geodetic networks. Currently, Gama only supports the adjustment of geodetic networks in a local coordinate system, but new developments are underway to support the adjustment of geodetic networks in global geocentric systems (Cepek and Pytel, 2009). To support field mapping, several GPS tools have been developed as plugins to open source GIS that allow the importing of GPS data. GPSBabel is an open source product that reads, writes and manipulates GPS waypoints in a variety of data formats. GRASS and Quantum GIS have included GPSBabel so that almost any GPS data format can be loaded directly into the software. On the Java side, the SurveyOS project aims to develop surveying tools for Open JUMP. A plugin that enables users to import survey points to Open JUMP has recently been released by SurveyOS.[2] BeeGIS[3] adds GPS support to uDIG users. With BeeGIS, users can receive data from a GPS and export it to PostGIS or shapefile. These GPS tools are mainly oriented towards handheld GPS units and do not yet include functions for differential correction and post processing GPS data, which would be needed for accurate cadastral surveying. The mobile version of gvSIG aims at adding more GPS tools in future releases, including support for DGPS and real-time differential correction.[4] Although a lot remains to be done in this field, it is encouraging to know that there are initiatives towards the development of open source surveying software.

6. SERVER SOFTWARE AND WEBGIS SERVICES

When it comes to web servers and server operating systems, the use of open source software has already been widely accepted. Research shows that two-thirds of European companies choose open source systems like Apache, Tomcat and Linux over proprietary alternatives (Ghosh, 2006). Also cadastre systems can benefit from the use of open source server software. Especially in the area of internet mapping and web enquiry systems, open source products are increasingly popular.

GeoServer, MapServer and Deegree are open source map server products focusing on internet mapping applications using OGC webGIS standards. These OGC interoperability standards such as WMS, WFS and WFS-T allow for the cross-platform exchange of geographic information over the internet. Using these standards, map data stored in Oracle Spatial, PostGIS or ArcSDE databases can be accessed over the internet with a standard web browser or GIS client software. With WMS, map data can be accessed and displayed as an image that can be overlaid with GIS data from other data sources to produce composite maps. With WFS, users can access the actual geographic features in vector format, while WFS-T allows for creation, deletion and updating of features. MapServer, GeoServer and Deegree are server-

[1] See http://www.gnu.org/software/gama/
[2] See: http://surveyos.sourceforge.net/
[3] See: http://www.beegis.org/
[4] See the gvSIG Mobile Roadmap at ftp://downloads.gvsig.org/gva/descargas/RoadMap/gvSIG_Mobile_Roadmap_03_2008_en.pdf

based "map engines" to display spatial data (maps, images or vector data depending on the OGC web service) over the internet to users based on their requests. In his State of Open Source GIS, Ramsey (2007) states that *MapServer is easily the most successful open source GIS project to date. It supports more input data sources than proprietary products, has higher performance and is simpler to install and set up.* And indeed, MapServer has proved to be a very mature and reliable product to distribute maps from GIS data sources over the internet through the WMS, WCS and other OGC interoperability standards. GeoServer and Deegree are more recent projects built with Java technology. While comparable to MapServer in many ways, GeoServer and Deegree go further by supporting transactional WFS services, allowing users to insert, delete and modify geographical data at the source from remote locations through the internet. In cadastre systems, this functionality would allow notaries to sketch new parcel boundaries resulting from property transactions on a digital map in their preferred GIS client software and send this new boundary information in the GML data format over the internet to the cadastral database on the WFS-T server (Brentjens et al, 2006).

A number of European cadastres already use WMS and/or WFS to give citizens access to public cadastral datasets over the internet, and are thus following the INSPIRE principles to provide public access to spatial datasets that are collected by the government. With the availability of high quality open source internet mapping tools, other national cadastre agencies are expected to follow this trend.

7. CONCLUSIONS

With the open source tools that are currently available, complete low-cost but robust cadastre systems can be built. For the storage of cadastral datasets, PostgreSQL with the PostGIS spatial data engine can be used. For the creation and maintenance of parcel boundaries, a variety of open source desktop GIS products is available. Through the map server tools GeoServer, MapServer and DeeGree, web geoportals can be created to make cadastral information available to the public. Although still in its infancy, gvSIG is developing a mobile GIS solution for the generation of tracks and waypoints, making it easier to record property boundary information in the field.

The software tools must of course be customized to fit the cadastral workflow according to the local requirements of land administration, but the same is true for proprietary software: there are no out-of-the-box solutions for cadastre systems. Specific cadastre tools must be developed that allow for the handling of parcel subdivisions and consolidations, while maintaining historic boundary information. Customization and localization are important aspects of building cadastre systems. The use of open source software tools gives developers of such systems the advantage that they *can* be customized to reflect the local language and culture of land registration.

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BIOGRAPHICAL NOTES

Gertrude Pieper Espada obtained her degree in Human Geography from the University of Utrecht in 1994. She has worked as a GIS consultant with IT companies in Germany, Portugal and Finland. She has also worked with F.A.O. in Honduras and in Rome. In March 2002 she started to work with FM-International Oy FINNMAP, and in October 2002 she joined the Finnish Technical Assistance Team as IT advisor for the Ministry of Land Management, Urban Planning and Construction in Cambodia. Since 2007, she has been involved in the joint FAO-WB-FIG Commission 7 FLOSS-Cadastre initiative to explore the possibilities of using free and open source software in land administration systems.

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