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Assessment of Open Source GIS Software for Water Resources Management in Developing Countries

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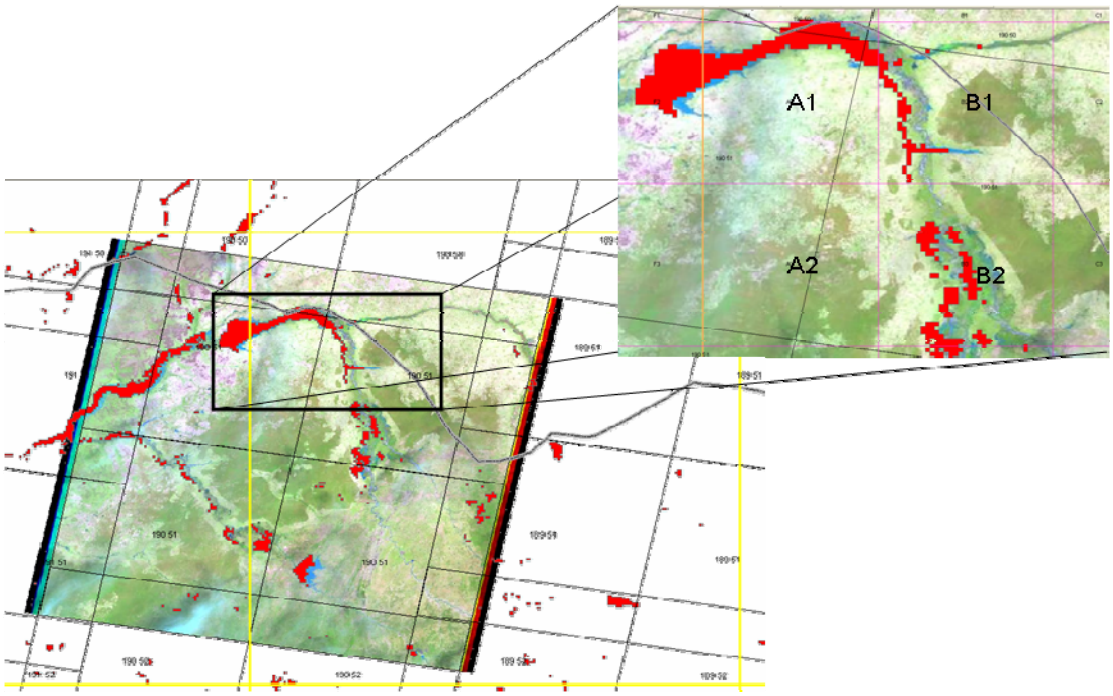

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Introduction

The Geographic Information Systems (GIS) has been developed for decades and commercial software packages have been successfully developed such as, for instance, ArcView and MapInfo. XML and Java have been developed to facilitate the development of the internet as well as providing a coding standard in the software industries. Around 2000, the OpenGIS Consortium (OGC, http://www.opengeospatial.org/) was formed under W3C. The OGC has drawn nearly all prominent institutes and organisations in the sector to join, such as IBM, Microsoft, Oracle, ERSRI, MIT, and Stanford University amongst others. The OGC has then published the Geography Markup Language (GML), Web Map Service (WMS) and Web Feature Service (WFS) to provide standardised ways of manipulating the GIS data. The XML and Java languages are in the core of the OGC releases. Thus, it has also made the development of the GIS software much easier. Therefore, in the last few years, there has been a significant development in the area of free and open source geospatial software. Research has flourished over the decades from vendor dependent software to open source software where researchers are paying increasing attention to maximize the value of their data so that resources can be utilised more efficiently. The term “open source” means that the source code is easily accessible (mostly under GNU license); the code can be modified, extended and/or distributed for non-commercial purposes benefiting the researchers, academics and other end users.

This study looks into the open source GIS software (over 30 GIS softwares) and their potentiality to identify and shortlist the most suitable, user friendly, efficient software which could be used for analysis or designing a system applicable to water resources management for developing countries.

As reported by Rajani (2003), who studied the relevance of Free Libre Open Source Software (FLOSS) for developing countries, FLOSS has the potential to contribute to democratization, education, capacity building and research. In particular, FLOSS can foster poverty alleviation "if the adoption of FLOSS in developing countries is done wisely, it can help stimulate indigenous software industry and create local jobs" (e.g in India, Madagascar,…). Unfortunately, the last 50 years of development aid are so far a story of developing dependence in terms of expertise, knowledge and technology development. Closed and licensed software market strategy is one of the barrages that keep developing countries in the vicious circle of poverty. FLOSS development towards a sustainable and long term capacity building can break that circle.

Concerning the particular use of Open Source in hydroinformatics and in GIS applied to hydroinformatics, Harvey (2002) affirms, in line with the principles of the Integrated Water Resource Management approach, that Open Source can have significant benefits for hydroinformatics, encouraging widespread interoperability and rapid development. This not only has technical and scientific advantages but can also be used for business market strategy and the community participative approach.

When presenting the different projects and their software, it is important to characterise the projects according to some unified criteria. The advantages and disadvantages will be analysed based on evaluation criteria established in this study. For this project, easy installation and running on personal computers are needed to allow users to display, query, update, and analyze data about geographic locations and the information linked to those locations. Only desktop GIS packages have been considered. This study discusses, in brief, the major features of each open source GIS software and then compares them in a tabular format based on the evaluation criteria. As the development of open source GIS has only several years' history, it is not easy to find a software package out of the relatively large number of projects to meet all the requirements.

1. Development of Assessing Criteria and Information Collection

1.1. Major Considerations in Development of Assessing Criteria

EU IWRM Guidelines and Water Knowledge Management Platform (WKMP)

The EU's guidelines entitled "Towards sustainable water resources management: a strategic approach" (hereinafter "the guidelines") were a good reflection of recent developments in Integrated Water Resources Management (IWRM), presenting a strategic approach to planning and managing activities relating to water resources, encompassing the drawing up of national policies, the use of services and the implementation of specialised projects and programmes. It has been identified that the guidelines are intended for all those involved in the development cooperation of water management and its use, including public entities and the private sector. The guidelines form part of the broader context of approaches adopted by the Member States of the European Union, the partner countries and other contributing parties. The EC - AIDCO has decided to update the guidelines by creating a Water Knowledge Management Platform (WKMP), with the intention of a wider collaboration and supporting relevant works within the EU as well as in developing countries.

There are a number of Water Knowledge Management Platforms based in the EU as well as all over the world. Advances in information technology and rapid changes in IT provisions for the water sector bring new opportunities for improving and enhancing the role of water knowledge management in the sector. The updating of the EC guidelines is one of many processes that would offer an opportunity for greater collaboration in Water Knowledge Management.

Open Source GIS

Open source software is becoming popular and increasingly more reliable than in the past. Considering the resource limitations faced by most developing countries, the utilisation of open source software is to be considered in the development of the WKMP. In addition to the cost issue, the inter-operability is the major challenge faced by possible collaborations between organizations.

One of the major EU legislations in the water sector is the Water Framework Directive in which river basins have been defined as the basic unit for water management. Therefore,

spatially distributed information such as water quantity and quality, water supply and collection networks, soil, vegetation and crops etc need to be gathered, processed and modelled for decision making. Geographic Information Systems (GIS) are effective in supporting the management and modelling of spatially distributed information. As an international standard for the development of a new generation of GIS, the OpenGIS standard has been developed in the past decade driven by the OpenGIS consortium under the W3C, primarily for the purpose of addressing the inter-operability issue. The XML has been adopted as the main language to present spatially distributed geographic and related information.

There are also efforts being made through EU projects, and a list of potential open source GIS tools have been published on the internet such as GeOxgene, Batik, Cascadoss, GeoAPI, GeoTools, JTC, JUMP, OJB and PostGIS. The advantages and disadvantages of those GIS tools need to be analysed.

Open source Operation System and Cross-platform

As we are looking for Open source GIS, the issue of open source operation system (OS) would naturally be brought up. Linux is a well-known open source OS and is getting more popular; however MS windows are still the dominant. Probably in the near future, support for both Windows and Linux would be necessary.

In recent years, cross-platform has been adopted by more developers as a basic requirement for software development. Cross-platform refers to software that can be made to work on multi-platforms, such as, Unix including Linux, Windows and Mac OS.

Cross-platform has been achieved in various ways. There are several platforms or programming languages used in the development of open source GIS, like Python and Eclipse in Java programming and .NET framework in the Windows environment. In most open source GIS projects, efforts have been made to achieve cross-platform interoperability so that they can run on Linux.

1.2 Assessment Criteria and Procedures

The main objective of this project is to select a few open source GIS software packages for the WKMP. Some selection criterions are established by considering a list of factors including:

- System requirements;
- Capacity, efficiency and reliability;
- Built-in applications;
- Interoperability;
- Ease and effectiveness of use;
- Ease of integration into the WKMP;
- Speed and demand for computing resources;
- Costs of utilization;
- Possible technical support.

After the preliminary selection process, the top candidates will be analysed in greater depth by considering more technical issues such as the detailed system integrations, matching of software versions between the database, operation systems, programming languages and user interface, graphic functions and internet connections, security and different level of authorisations etc.

The benefits and costs will need to be analysed to strike a balance. Some compromises may be needed since no system would be perfect in every single aspect. If the main requirements are satisfied, the two top candidate systems can then be recommended for the WKMP, and may need further modifications.

1.3. Information Sources for Open Sources GIS

Websites on the Internet

Information of open sources GIS have been collected from all possible sources on the internet. Several very useful links are:-

- Open Source GIS (http://opensourcegis.org/) This site attempts to build a complete index of Open Source / Free GIS related software projects. The definition of GIS has been kept loose to encompass a broad range of projects which deal with spatial data. This site stands on the sturdy shoulders of other projects, most notably OSRS , FreeGIS.org, Metalab Linux Archive, and Fresh Meat.net. A list of over 250 GIS related software packages is provided.

- Freegis (http://freegis.org/) This site organise software, geodata projects etc according to the OS, language features. More than 300 relevant softwares were collected.

- SourceForge (http://web.sourceforge.com/) This is a site for all sorts of open source softwares. It helps to maintain and provide codes for downloads.

- OSGeo (http://www.osgeo.org/) This is the website of *The Open Source Geospatial Foundation* that has been created to support and build the highest-quality open source geospatial software. A list of very popular software packages are listed as OSGeo projects in the OSGeo website.

Web Mapping	Desktop Applications	Geospatial Libraries	Metadata Catalog
deegree *	GRASS GIS	FDO	GeoNetwork
Mapbender	OSSIM *	GDAL/OGR	
MapBuilder	Quantum GIS	GEOS *	
MapGuide Open Source	gvSIG *	GeoTools	
MapServer *			
OpenLayers			

- GISwiki (http://en.giswiki.net/wiki/Category:Software) lists both commercial and open source softwares.

- Cascadoss (http://www.cascadoss.eu/en/index.php) is a European project and a list of open source GIS has been compared at (http://www.cascadoss.eu/en/index.php?option=com_content&task=view&id=14&Itemid=14)

- Wikipedia provides a list of open source GIS software packages (http://en.wikipedia.org/wiki/List_of_GIS_software) and comparisons of some packages were given at (http://en.wikipedia.org/wiki/Comparison_of_GIS_software). It is noted that both commercial and open source softwares have been included.

Links for open source GIS from the above sites were used to search for more information in the present project. Often some developers for open source GIS may only have support for a limited time to their projects. Some software packages are placed at several websites with different versions. All of these create difficulties in searching for information on the web for open source GIS package.

2. Assessment of Open Source GIS Software

2.1 Screening of Open Sources GIS Software Packages

Through various extensive searches, several hundreds of GIS relevant software packages were found. An initial screening was based on two criterions: (a) general purpose DeskTop GIS applications and (b) currently active, which means that updates occurred in the last couple of years. For example, a number of web-GIS packages were excluded, such as, MapServer, OpenLayer, PrimaGIS etc. A list of 31 open sources GIS software packages has been put together as serious candidates to be considered for the project. The name, version of release, developer and homepage are shown in the following (Table 1a).

Table 1a: List of Desk GIS candidate software

Name	Release	Developer	Homepage
Apache Batik	V1.6	Apache	http://xmlgraphics.apache.org/batik/
DIVA GIS	V6.0.3	CIP (International Potato Center, Peru)	http://research.cip.cgiar.org/confluence/display/divagis/Home
Deegree	V2.1	lat/lon, Germany	http://www.deegree.org/
Fmaps	V0.0.2	Fmaps team	http://sourceforge.net/projects/fmaps/
FWTools	V2.0.6	Private	http://fwtools.maptools.org/
GeOxygene	V1.3	GeOxygene Team	http://oxygene-project.sourceforge.net/
GeoServer	V1.6.4	Geoserver team	http://geoserver.org/display/GEOS/Welcome
Generic Mapping Tools	V4.3.1	Univ of Hawaii	http://gmt.soest.hawaii.edu/
GRASS GIS	V.6.2.3	GRASS Development Team	http://grass.itc.it/

gvSIG	V1.1.2	Iver, Generalitat Valencia, Universidad Jaume I, Prodevelop	http://www.gvsig.gva.es
HidroSIG	V.3.1.1	University of Colombia, Sede Medellin	http://cancerbero.unalmed.edu.co/~hidrosig /ingles/index.php
ILWIS	V3-04-02	52° North	52°North Product page
KOSMO	V1.2	SAIG S.L.	http://www.opengis.es/
JTS Topology Suite	V1.8.0	VIVID SOLUTIONS	http://www.vividsolutions.com/jts/jtshome.htm
Mapnik	V.0.5.1	BerliOS Developer	http://mapnik.org/
MapWindow GIS	V4.5SR	MapWindow Open Source Team	http://www.mapwindow.org
mezoGIS	V.0.1.5	Private, frozen now	http://www.mezogis.org/
monoGIS	V0.7	MonGIS team	http://www.monogis.org/
NRDB	V.2.3	Private	http://www.nrdb.co.uk/
OpenJUMP	V1.2	OpenJUMP Team	www.openjump.org
OpenMap	V4.6.4	BBN Technologies	http://openmap.bbn.com/
OSSIM	V1.7.9	OSSIM team	http://www.ossim.org/OSSIM/OSSIMHome.html
PostGIS	V.1.3.3	Refractions Research	http://postgis.refractions.net/
Quantum GIS	V0.11.0 (July2008)	QGIS Development Team	http://www.qgis.org
SAGA	V2.0.3	Univ of Goettingen	http://www.saga-gis.uni-goettingen.de/
SAMT	V.2.8.1	Institute of Landscape Systems Analysis (ZALF)	http://www.zalf.de/home_samt-lsa/
SavGIS	V2.1.5.0	IRD (Development Research French Institute)	http://www.savgis.org
SharpMap	V0.9	sharpmap team	http://www.codeplex.com/SharpMap
TerraView	V.3.2.0	DPI of INPE	http://www.dpi.inpe.br/terraview/index.php
Thuban	V.1.2.1	Thuban Team	http://thuban.intevation.org/
uDIg	V1.1-RC14	Refractions Research	http://udig.refractions.net

Information on the operating system and the programming language has been collected for all the software in Table 1a, and comments are also made in Table 1b below. It has been noticed that there are broadly two types of open source GIS softwares. The first type was developed in the past with a relatively long history like savGIS and ILWIS. They were developed for internal use in the early days and then they have decided to make it open to the public as the openGIS became the new trend of development. The second type was developed recently to catch up on opportunities offered by the openGIS standardizations in the GIS field. As the GIS development became much simpler than before, it had promoted the development of open source GIS and a number of projects are still undergoing. The list to be discussed here only reflects a snapshot at the current time, and the picture may change remarkably in the future.

Table 1b. Operation system, programming language and comments to open source GIS

Name	Operating System	Programming Language	Comments
Apache Batik	Windows, Linux	Java 1.3	Limited to SVG functions
DIVA GIS	Windows only	Java with Eclipse	Java, Eclipse RCP like uDig, but only for Window so far
Deegree	Windows only	Java 1.5, tomcat 5.5	For Server/client web applications
Fmaps	Linux and Gnome	C	For Unix only
FWTools	Windows, Linux	Java, python	A comprehensive package, too complex
GeOxygene	Independent	Java	in the middle of development
GeoServer	Mac, Unix, and Windows	Java 1.4	For web-GIS, installation difficulties
Generic Mapping Tools	Windows, Linux, mac	C/C++	Tools only
GRASS GIS	Unix (Linux,) Window	C	Large and complex
gvSIG	Windows, Linux, Mac OS	Java	Good computing resources management
HidroSIG	Windows and Linux	Java	Latest release in 2005, working language and installation instruction in spanish
ILWIS	Windows only	MS Visual 6	to be converted to Java, unstable
KOSMO	Windows, Mac OS X, Linux	Java	From the JUMP project
JTS Topology Suite	Windows, Linux	Java	OGC Simple Features Specification for SQL
Mapnik	Windows, Linux, Mac OS	C++, python	Tool kits only for making pretty maps
MapWindow GIS	Windows only	.NET(VB,C++,C#), .Net framework 2.0	Rich functions in water resources
mezoGIS	Linux and Windows	Python	python programming language, improve postGIS's SQL workflow
monoGIS	Linux and Windows	OGR/GDAL (C++), Shapelib (C), Net Topology Suite (.NET, C#), Geotools.	Powerful, but in early development stage
NRDB	Windows only	C++	more for database, simple map functions

OpenJUMP	Windows, Mac OS X, Linux	Java	Easy to use
OpenMap	Windows, Linux, Mac OS	Java	Insufficient functionalities
OSSIM	Windows, Linux, Mac OS	C++	for remote sensing mainly
PostGIS	Windows, Linux, Mac OS	C	Support spatial database
Quantum GIS	Linux, MS-Windows, Mac OS X, POSIX	C++	powerful system
SAGA	Windows and Linux	C++	Advanced analyses functions
SAMT	Unix	?	too specific landscape modelling tools, too complx to install
SavGIS	Windows only	?	Old fashion
SharpMap	Windows only	C#, .NET, meno, Ermaper ECW SDK	CLR (common language runtime), .NET or Meno
TerraView	Linux and Windows	C++	related to Terralib, the homepage is in Spanish
Thuban	Linux, Windows and Mac OS	Python	Simple functions
uDIg	Windows (not window2000), Mac OS X, Linux	Java with Eclipse	Good openGIS implementation

As the aim of the project is for Desktop applications in the water resources fields for developing countries, a preliminary screening has been done to pick up the most suitable ones that are balanced, with easy to use and sufficient GIS functions. The following observations were made to the listed open source GIS in Table 1.

<u>Sufficient functionalities as a Desktop GIS system</u>

Some packages only served as tools or libraries so that they would not be shortlisted.

- GMT
- OpenMap
- Apache Batik (for handling SVG)
- Mapink (for map presentation)
- MezoGIS (improve postGIS's SQL workflows)

Some packages like Thuban and OpenEV have relatively simple functions.

<u>Level of complexity</u>

- The most powerful GRASS software was not selected as it may be more complex.
- OSSIM is very large (600Mb to 1Gb download for a full version)

Maturity

Some packages may have great potential in the future but are currently still in the early or middle part of their developmental stages such as:

- GeOxygene
- MonoGIS
- Terraview

Cross-Platforms requirement

Some packages only work on either Windows or Unix; so they may be excluded from further consideration if cross-platform become a compulsory requirement.

- DIVA GIS (Windows only)
- Deegree (Windows only)
- FMaps (Unix and Gnome)
- ILWIS (Windows only)
- MapWindow GIS (Windows only)
- NRDB (Windows only)
- SAMT (Unix only)
- SavGIS (Windows only)
- SharpMap (Windows only)

Some of the single platform softwares like SavGIS and ILWIS may be due to historical reasons.

The above considerations are more for deselecting some softwares. However, the following considerations are for selecting the various candidates to the shortlist.

Popularity of the Software

For various reasons, there are some software packages which have drawn more attention to the user community, and they may be used more widely and developed further in the future. Some names mentioned in the OSGeo homepage for DeskTop GIS are:

- GRASS GIS,
- OSSIM *,
- Quantum GIS,
- gvSIG *

In the European CASACDOSS project, the following software packages were compared:

GRASS	QGIS
OSSIM	Thurban
OpenEV	OpenMap
gvSIG	uDig
Saga GIS	JUMP
FMaps	Kosmo

2.2 Installation and Test Running of Potential Candidates Open sources GIS

Based on the above considerations, the following 14 open source GIS packages shown in Table 2 were downloaded. Subsequently they were installed in a 6 years old Desktop PC of AMD Athlon™XP 2800+, 2.13GHz, 512MB of RAM, under MS Windows XP home edition, version 2002, service pack 2. A relatively new Sony laptop computer with MS Windows Vista has also been used to test the Vista compliance. The prerequisites and outcomes of the installations are presented in Table 2 below.

Table 2. Installation of 14 open source GIS

Name	Prerequisites	Download File Size (Mb)	Installation
DIVA GIS V6.03.0	Java and Eclipse	120	OK on both XP and Vista
FWTools	Java, Python	20.3	OK on both XP and Vista
Geoserver	Need JAVA JDK1.4 or newer	36.7	Easy to install but not run on both Vista and XP
GeOxygene	Java	10.6	Problems in installation
GRASS	Python	44.3	OK on XP
gvSIG	VJM1.05.12,JAI 1.1,JAI image I/O 1.0 (16+6+10Mb)	69.4	Easy, need to install 3 Java programmes. Ok with XP, but cannot read image files in Vista
HidroGIS	Jre1.4.2	155	installation instruction in spanish, hard to guess
ILWIS	No	13.5	Run directly
MapWindow GIS	No need for JAVA; Net framework 2.0 is needed for XP (can be downloaded during the installation)	34.1	Easy and ok for XP
OpenJUMP	JRE1.5.0 (happy with the jre1.05.12 for gvSIG)	11	Easy
Quantum GIS V0.11.0	Python 2.5.2 (10.7Mb)	73	cannot be installed in Vista; ok in XP
SAGA GIS	No	7.4	Run directly
SavGIS	No	10.5	Easy
uDIg	jre1.05.12 + a special uDIGSDK kit including Java and Eclipse, 79.7Mb (not Java SDK)	85.4	Easy

Among the 14 softwares, the Geoserver had problems in the use of the graphical interface. The GeoOxygene could not be installed and it may be due to the fact that it is still in the middle of the developmental process. The HidroGIS's installation instruction and working language are in Spanish and does not match the objectives of this international project. The FMTools are a combination of the openEV map/image viewer and a common-line interface. The SavGIS is not user friendly enough. After the installation, the Geoserver, GeoOxygene, HidroGIS, FMTools and SavGIS were not selected for further consideration. It was found that there was a plan to convert ILWIS to a Java-based system so its stability is in doubt. Although GRASS had been successfully installed, it was excluded beause it might be too complex for practitioners in the field with limited computer skills and GIS knowledge.

2.3 Assessment of the performance of open source GIS

The remaining software packages from the above screening exercise were installed OK on MS Windows XP. But gvSIG cannot open image files in Vista and QGIS cannot be installed at all on Vista. It is hoped that the problems with Vista will be sorted in future releases. Therefore, further running tests were conducted for the rest of the 8 software packages. Detailed comparisons were then conducted in several aspects.

Data format and database

Table 3: Database compatibility and data format for different GIS softwares.

Name	OpenGIS	Database	Data format
Diva GIS	WMS, WFS	Yes	Shp, grd,tif,ipg,sid,arc
GvSIG	WMS,WCS ,WFS (ArcIMS)	Yes	shp, gml,dxf,dwg,dgn,geoBD,WFS,WMS,WCS,ArcIMS
MapWindow GIS	WMS,WFS	Access, ArcXML	shp,bgd,bil,asc,ESRI grid, img,ESRI FLT,ddf,aux,dhm,bt,bmp,ecw,map,sid,LFT,kap,wmf
OpenJUMP	WMS	Yes	ESRI (shp), ecw,gml,xml,fme,jml,wkt,txt, WMS, database query
QGIS	WMS	PostGreSQL	ESRI (shp), mapinfo (mif), cadd, ddf,gml,tif, img, dem,asc,dt0,
SAGA GIS	No	Via ODBC	ESRI E00, GPX, GDAL, DXF, SBF, ODBC
TerraView	No	Yes	Tif, jpeg, SPR, RAW,ASC,txt,grd
uDIg	WMS, WFS	ArcSDE,DB2 ,Oracle, ArcSDE, PostGIS	ArcSDE,DB2,Map Graphic,Oracle Spatial, postGIS, WFS,WMS

Amongst the 8 software packages in Table 3, SAGA GIS, SAVGIS and TerraView can only recognise limited data formats. They also do not have compliance with the openGIS standards. However, the rest of them used the latest libraries, and so they could support the majority of popular data formats.

Table 4. Performance of 8 open source GIS

Name	Reading 125Mb tif Image (second)	Panning a 125 Mb image	Time for Zooming	Conclusion
Diva GIS	V6.03 is very slow as uDig	Took a long time	Long	Not acceptable for large size images
GvSIG	3	Easy	<2	
MapWindow GIS	12	Easy	1	
OpenJUMP	3	Easy	1	
QGIS	3	Easy	1	
SAGA GIS	Cannot read .tif			Too few image formats
TerraView	Failed to read 125Mb file, read a 47.7 tif image in 15 seconds			
uDIg	125Mb is too big to handle, read a 47.7Mb tif image in 350s	Took more than 350s for a simple navigation function or zooming on a 47.7Mb image	400s	Not acceptable for large size images

From the above test results on the 6 years old AMD Athen desktop PC, as mentioned in previous sections, the start-up times of TerraView and QGIS were around 10 seconds. The rest of the packages took 20 seconds to 1 minute to start up. Because handling large size images may be one of the most resource demanding jobs in GIS, two large image files in TIF format (47.7Mb and 125Mb) were used to test the GIS map rendering functions such as reading, panning and zooming. The SAGA software cannot read the TIF format image. The uDIg and the new version (6.03) DIVA GIS packages were very poor in handling large files. As indicated in Table 4, the uDIG took a hundred times longer to get the data read in the 47.7 Mb image, and every single step in rendering the image would take approximately 300 to 400 seconds. The DIVA GIS's performances were similar to the uDIG, probably due to the fact that both of them used the Geotools image library. On the other hand, the uDIG and DIVA GIS packages have a unique friendly feature that enable layers to be added to the map by dragging the file and dropping it into the map window. In contrast, the gvSIG, MapWindow, openJUMP and QGIS performed satisfactorily in opening and rendering large size images.

Conclusions drawn from the running tests are:

- Diva GIS (V6.0.3) and uDIG were dropped due to very disappointing performance of opening and rendering large image files.
- SAGA GIS and TerraView were dropped due to their relatively limited data formats and functionalities.

2.4 Systematic Assessments to the Top 4 Candidates

From now on, only 4 candidate softwares will be considered further:

- C/C++ software packages: QGIS and MapWindow GIS
- Java software packages: gvSIG and openJUMP

Table 5: General features of the 4 candidate softwares.

Functionality	GvSIG	MapWindow	OpenJUMP	QGIS
Working Language	Multilingual (CA, DE, EN, ES, EU, FR, …)	CA, DA, DE, EN, ES, EU, FR, GL, IT, PT, Nederlands, Norsk, Suomi	Only English (may be translated but complex)	At least: English
Manual language	English, spanish and Itanian	English (Spanish for ActiveX).	Germany, french, english	English, German and Italian
Capacity, efficiency and reliability	High	Very rich water related plugins	Medium, includes plug-ins and standard GIS data visualization features	High, efficient and reliable
GIS Data Interoperability Via openGIS	Yes	Yes	Yes	Yes
Cross Platform	Yes	No. Supports Windows Platform only	Yes	Yes

Easy to use and to be effective	Yes	Yes	Yes	Yes
Demand for computing resources	Medium	High	Medium	Low

The general features for the above open source GIS softwares are documented in Table 5. It is observed that gvSIG, openJUMP, MapWindow GIS and QGIS are all satisfactory in terms of their ease of installation, user-friendliness, efficiency, capability and wider accessibility of data in different formats.

Functionality

Furthermore, as shown in Table 6, these software packages were studied in detail including their read and write access (Vector and Raster Data), database link, OGC compatibility, thematic mapping, GPS support, scripting functionality, coordinate projection, watershed, terrain and 3D analysis.

Table 6: Showing detail of short listed potential open source GIS softwares

Functionality		**gvSIG**	**OpenJUMP**	**MapWindow GIS**	**QGIS**
Vector Data	**Read**	SHP, DXF, DGN, DWG, GML	Shp, FME GML, JML, WKT, MIF(p) DXF(p)	At least: SHP, DXF(P), CSV(P), Waypoint+(P)	At least: SHP, GML, TAB, CADA,DAF, MIF
	Write	SHP, DXF, GML	Shp, FME GML, JML, WKT, MIF(p) DXF(p) SVG	At least: SHP	At least: SHP, GML, TAB, CADA,DAF, MIF
Raster Data	**Read**	ECW, MrSID, JPEG,jpg, jp2, TIF, geoTIFF, PNG, GIF, img, bmp, jpeg2000	tif, GeoTIFF, png, jpg, ecw(p), mrSID(p)	At least: JPEG, GeoTIFF, ECW, ArcInfo GRID; all GDAL supported	At least: IMG, ASC, DAF, DT0, DEM, AIG, GRASS

	Write	ECW, MrSID, JPEG,jpg, jp2, TIF, geoTIFF, jpeg2000	png, jpg	At least: JPEG, GeoTIFF, ArcInfo GRID; all GDAL supported	At least: Png, jpg
Database Links (R: read, W: write)	PostGIS	R,W	R, W(p)	R+W(p)	R,W
	ArcSDE		R(p)	No	
	Oracle	R,W	R(p)	No	
OGC Compliant / supported OGC standards		WMS, WFS, WCS, CSW, Filter, WFS-G	SFS, WMS, GML, WFS(p)	WMS (P), WFS (P)	WMS, WFS(p)
Thematic Mapping (e.g. Bar Chart • Graduated Symbol • Individual Value • Pie Chart • Label • Ranges • Dot Density)		yes (simple)	Yes (p)	only labels; others in development	Yes
Developer API		no	Yes	Yes	Yes
Scripting Functionality		Jython	Beanshell Jython(p)	C#,B.Net	Python
Coordinate Transformations/ Projections		yes	Yes(p)	Yes	Yes
Data creation and Editing (The creation of new 2D graphics including lines, polylines and freehand lines. Area tools include areas, multiareas, ellipses, circles, and rectangles. Point tools include points, multi-points, and shapes. Also, familiar CAD–like precision tools such as snap and typed coordinate input.)		yes	Yes	Yes	Yes
GPS support		no	No	Yes	Yes
Topology creation and editing (Creation of link,node, chain and polygon topology)		yes (lines)	Yes (limited)	TIN creation per API; viewing/ creation via plug-in	Yes
Advanced data creation & editing (including item snapping, creating offsets, line generalisation, trimming, rotating, etc.)		yes	Yes (except offsets)	Yes (except generalisation)	Yes
Advanced thematic mapping (Including Thiessen polygon analysis, grid analysis, contour mapping and flow-line generation.)		yes	Thiessen polygons (for specific cases)	Yes (contour and flowline generation)	Yes

Creation of 3D views & terrains (Creation of triangulated irregular networks (TINs) and digital terrain models (DTMs), relief shading and surface draping of raster images and vector data for 3D visualisation purposes. Includes support for constrained Delaunay triangulation, allowing TINs to be created from a collection of surveyed elevations, with optional breaklines and bounding areas.)	yes	No	Yes (3D plugin, TIN for API only, hillshade)	Yes
Viewshed and terrain analysis (provides line-of-sight calculations used to determine all areas on DTM data that are visible from a chosen location, plus slope, aspect, and gradient grid analysis.)	yes	No	Yes (watershed analysis and terrain analysis)	Yes

(p) = functionality provided via external plugin

In the final shortlist, there are two C/C++ language GIS packages, namely QGIS and MapWindows. The QGIS can run on multi-platforms, and it is adequately powerful and easier to use than GRASS. MapWindow GIS can only run in MS Windows. Its advantages lie in the rich water-related functions.
In the two Java GIS packages, gvSIG is very easy to use and also powerful. The OpenJUMP software is very useful too but it has less functionalities than the gvSIG. Therefore, gvSIG appears to be relatively more suitable than the openJUMP.

Considering that certain users in some developing countries may still use aged computers that have very poor computing powers, further tests were conducted on a 10 years old Pentium III PC to reach the final decision of recommending the top software packages.

Further Installation and Running Tests on a Pentium III PC

The 4 open source GIS packages in the shortlist were further tested in a 10 years old laptop computer with Pentium III 450MHz, 328 Mb RAM, MS Windows 2000, Service Pack 4.

Python 2.4 was installed prior to the installation of QGIS. Java running environment was also pre-installed for the openJUMP package. In general, the installations of QGIS and openJUMP were quite straightforward and the lengths of time taken were acceptable, that is,within several minutes. The gvSIG required two more Java libraries, in addition to the Java running environment, and the installation took approximately 20 minutes. The MapWindow requires Windows Installer 3.0 and .NET Framework 2.0, which took more than 30 minutes to be installed. The installation of MapWindow itself was also very slow and it took approximately another 30 minutes, probably due to the installation of sample projects with large image files. The performance results of the 4 softwares on the Pentium III PC are listed below in table 7.

Table 7. Performance of 4 open source GIS on a Pentium III PC in Windows 2000

Name	Time to start up the program (second)	Reading 125Mb TIF Image (second)	Time to settle after panning a 125 Mb image (second)	Time for Zooming (second)	Performance rank under very poor computing resources
QGIS	35	4	1	2	1
OpenJUMP	345	17	1	4	2
gvSIG	560	16	3	8	3
MapWindow GIS	90	225	Could not pan over the image	2	4

This Pentium III PC must be regarded as a very old computer, even in developing countries. PCs with such configurations represent conditions of extreme poor computing resource. The QGIS performed comfortably under this extreme condition. It started up in 35 seconds, which is acceptable. It opened a large (125Mb) image in 4 seconds and only took one to two seconds to pan and zoom the image. Therefore, it has to be ranked as the number one among the 4 packages in the tests.

The startup times of gvSIG and openJUMP were 345 seconds and 560 seconds respectively, which were far too slow to tolerate. However, both performed comfortably in handling a large (125 Mb) image, including opening, panning and zooming, but openJUMP was slightly faster.

MapWindow's startup time of 90 seconds was long. It also took a very long time to open a large image (125Mb) and failed to get the panning function working properly. However, the zooming function worked fine. It appears that MapWindow had struggled.

In summary, under the very poor computing conditions, the QGIS outperformed the rest, followed by the OpenJUMP and the gvSIG. One apparent disadvantage of the OpenJUMP and gvSIG is that the starting up time is quite long, perhaps due to the Java language. The performances of MapWindow in reading and rendering maps were poor. However, its starting up time is short, probably due to the nature of the C/C++ programming which has already been demonstrated by QGIS too.

An important lesson learned from this exercise is that the perceived hardware constraint in developing countries may not be a real big issue, at least for relatively simple GIS applications. At the beginning of this project, constraints in both hardware and software supports in developing countries were of serious concerns. After running the test above, it was felt that computing hardware in developing countries should be adequate for simple GIS application, such as, in WKMP. As it has been shown, any GHz and 500 Mb RAM computers can comfortably handle most GIS map rendering and processing tasks, up to an image size of 100 Mb. We should focus more on the possible constraints in software support in developing countries and pay more attention to provide truly user-friendly interfaces.

Discussion and Conclusions

The purpose of this study is to choose suitable open source GIS software packages for potential WKMP users in developing countries. Amongst a list of criteria, relatively easy to use and poor computing conditions have been emphasised. A 10-years old Pentium III PC was used to create an extreme poor computing condition as those we can find in developing countries in order to create a realistic hardware-software environment. Furthermore, the capability of rendering large size images has been chosen as an important indicator.

QGIS performed extremely well under very poor computing conditions and its functionalities are adequate for most general applications in water resources management. Its functionalities may be enhanced by linking to GRASS. Based on balanced consideration of all discussions made above, a conclusion can be drawn that QGIS is obviously the top choice for the WKMP.

MapWindow has performed satisfactorily under relatively weak computing conditions but not acceptable at the very poor computing conditions. However, it has very rich water related functionalities and the list of plug-ins is still increasing. MapWindow is also recommended for the WKMP.

Both gvSIG and openJUMP offered balanced performance in efficiencies and functionalities at an acceptable level. The GvSIG seems to perform slightly better than the openJUMP and thus it is recommended to the WKMP too. The OpenJUMP could possibly be a good reserve.
Furthermore, amongst the rest of the open source GIS packages, if the uDIG and DIVA GIS packages can improve their map rendering functions, they are potentially very user-friendly software packages. A number of GIS software packages are still in their developmental processes; hence, it is expected that some interesting packages would be released in the near future.

This recommendation of QGIS and gvSIG is consistent with the conclusion of the CASCADOSS project. They have scored a list of open source GIS software in three headings: Market Potential, Technical Potential and Economical Potential. The adding up of the three headings has produced a ranking list as shown in Table 8, in which GRASS is the number one package, followed by QGIS and gvSIG. As the WKMP is for developing countries, GRASS was not recommended in the present study because it was not as easy to use as the QGIS and the gvSIG packages.

As has been emphasised from the beginning, this study can only provide a snapshot in an area that is moving quickly. A similar review is recommended every 2 to 3 years. An important issue is the change of version. For example, as DIVA GIS developed from version 5.2 to 6.03, the software became more powerful in many aspects; however, the speed of map rendering has been significantly reduced to an unacceptable level. Unfortunately, if the WKMP is going to rely on open source GIS software in the community, this version change problem would be an issue forever.

Table 8. A ranking list of open sources GIS from a combined index from indices obtained in the CASCADOSS project.

Market+Tech+ Economic		
Type	**Software**	**Total Score (%)**
GIS/RS app.	**GRASS**	**81**
	gvSIG	**70**
	OSSIM	**69**
	OpenEV	**66**
	SAGA GIS	**62**
	FMaps	**34**
GIS app.	**QuantumGIS**	**82**
	Thuban	**74**
	OpenMap	**67**
	uDig	**64**
	JUMP	**62**
	Kosmo	**57**

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Abstract

The European Commission is developing, under the responsibility of the Joint Research Centre and in close collaboration with international and national partners, the Water Knowledge Management Platform. This platform will integrate a dynamic management of different support tools and guidelines for the water management sector in developing countries. The support tools will be based on open source desktop GIS technologies in order to provide the final users in developing countries with a sustainable technology from both financial and technological points of view.

In this study, a comprehensive list of several hundred open sources GIS software packages are put together by an extensive search and then screened to obtain a list of 31 packages for further consideration. Various criteria were developed to exclude 17 packages and the remaining 14 went through a series of installation and performance tests; firstly, on a six years old PC (AMD Athlon™XP 2800+, 2.13GHz, 512MB of RAM, under MS XP). Several packages were dropped due to the general suitabilities and functionalities. Four packages (QGIS, gvSIG, MapWindow and openJUMP) performed well in map rendering of large file sizes (up to 125Mb) and were further tested on a Pentium III computer. The QGIS package outperformed others in very poor computing conditions. The gvSIG and openJUMP packages performed reasonably well but their start-up times were long, while MapWindow struggled. QGIS, gvSIG and MapWindow were recommended for the EU Water Knowledge Management Platform (WKMP).

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