# OPEN SOURCE GIS

## *A GRASS GIS Approach*

### *Third Edition*

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*by*

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to our friends and to all GRASS developers, present and past

# Foreword

GRASS GIS software was developed in response to the need for improved analysis of landscape "trade offs" in managing government lands and the emerging potential of computer-based land analysis tools. During the last decades of the 20th century, government land managers in the U.S. (and across the world) faced increasing requirements from legislation and stakeholder groups to examine and evaluate alternative actions. To fulfill these new requirements, land managers needed new tools.

During this same era, computational capabilities wondrously improved. Tasks requiring days and months with paper and acetate overlays could be accomplished with this newly emerging geographic information technology within minutes. But even in the mid-1980s, GIS technology involved significant capital investment. Managers wanted to see results before they spent their limited funds on new technologies.

The U.S. Army Construction Engineering Research Laboratory (CERL) in Champaign, Illinois has the mission of developing and infusing new technologies for managing U.S. Department of Defense installations. These installations include millions of acres of lands needed for military training and testing. Other uses included wildlife management, hunting and fishing and forestry, grazing and agricultural production. Other priorities were added through legislation – such as protecting endangered species and habitats, protecting cultural sites, and limiting the on and off-post impacts of noise, ordnance, contaminants and sediments.

Military land managers were unable to cope with the challenge of examining proposed new actions (such as new weapon firing ranges or new vehicle training routes) without improved methods to gather, integrate and visualize their data and to examine alternative courses of action. Acquiring emerging proprietary technologies and digital data wasn't even a consideration – the cost was too high and the expertise required to learn, operate and manage the technology was beyond their resources.

Given this need, a group of then young researchers at CERL elected to develop their own set of initial landscape analysis tools. Initially, this in-house

software development effort was designed to "bridge the gap" as commercial proprietary technology developed. The other costs involved in implementing GIS (acquiring data and hardware, learning GIS skills and computer maintenance skills) were so high; CERL decided that no-fee software could reduce the technology hurdle involved in implementing GIS. This proved to be true – and U.S. military installations were some of the first government managers to become active users of this new technology.

Once our efforts began, software development took on a life of its own. The Open Source code and Internet accessible software soon sparked the creative energies of numerous other organizations and individuals, and many began to use GRASS and contribute capabilities. At CERL, a small-scale skunk works project became the biggest and hottest program in the lab. Dozens of persons were employed developing new tools, building digital databases, assisting with complex applications and fielding the technology across the Department of Defense.

The needs we addressed drove the design criteria for GRASS. Because of the requirement to analyze alternative actions and to evaluate impacts of actions on continuous surfaces of differing elevations and vegetation and soil types, GRASS development was focused on raster analysis tools. Also, because of the need for digital and "real time" data, GRASS also incorporated remotely sensed image integration and analysis tools. At the time, this focus set GRASS apart from marketplace capabilities, which were primarily based on vector data and tools and did not include image analysis.

To nurture a "growing" GRASS community, CERL and other organizations established forums for sharing and contributing software. For several years, the lab (and lab partners) also offered newsletters, developed formal interagency partnerships (primarily with the U.S. Department of Agriculture and National Park Service) and held annual software user meetings. During the early 1990s, this GRASS community helped to initiate the Open GIS Foundation (now the Open GIS Consortium) as an international organization focused on advancing openness and interoperability for geospatial technologies.

But by the mid-1990s, many of the original military installation GIS users were switching to proprietary marketplace GIS technologies. In the intervening years, marketplace GIS vendors had added raster analysis tools, much like those in GRASS. Installation managers had become dependent on GIS, and were now willing to buy from the marketplace. Generally, the government is expected to buy off the marketplace, unless there are no comparable marketplace options. Plus, installation managers wanted GIS software just like the systems that were showing up in the offices of supporting contractors and local and state government offices across-their-fence lines. As a result, CERL managers decided they had achieved their purpose of "bridging the gap" in introducing this new technology. CERL entered into agreements with GIS vendors, and helped installations transition their data to proprietary systems. Army research programs were directed to new challenges.

Fortunately, in the years since CERL stopped active development and support of GRASS, the Universities of Hannover (Germany), Baylor, Texas (U.S.A.), and recently the ITC-irst – Centro per la Ricerca Scientifica e Tecnologica (Italy) have continued to coordinate the development of GRASS GIS, performed by a team of developers from all over the world. Thanks to their efforts, GRASS GIS keeps getting better, and valuable and reliable Open Source GIS capabilities are still available through the Internet.

Those of us at CERL are grateful for these academic efforts. GRASS remains an unique capability that continues to play an important role in education and in the advancement of scientific understanding and resource management. The analysis tools within GRASS and the access to source code provide important benefits in our ability to understand and model geospatial phenomena. Plus, developers of this Open Source GIS continue to pioneer and advance capabilities that later emerge in the proprietary geospatial marketplace.

Thanks to the authors, this book should help sustain these important roles for GRASS GIS for years to come.

USA CERL *William D. Goran*

# Preface third edition

Geographical Resources Analysis Support System (GRASS) is one of the largest Free Software Geographical Information System (GIS) projects released under the GNU General Public License (GPL). It combines powerful raster, vector, and geospatial processing engines into a single integrated software suite and includes tools for spatial analysis, modeling, image processing and sophisticated visualization.

With this third edition of *Open Source GIS: A GRASS GIS Approach*, we enter the new era of GRASS 6, the first release that includes substantial new code developed by the International GRASS Development Team. It comes at a time when dramatic growth in acceptance of the Open Source concept fuels further development of Free and Open Source Software for Geoinformatics (FOSS4G) and brings interoperability to a new level of efficiency. The major FOSS4G projects, including GRASS, have become part of the OSGeo foundation – an organization established in 2006 to "support and promote the collaborative development of open geospatial technologies and data." Following the spirit of the foundation, GRASS is tightly integrated with the latest GDAL/OGR and PROJ libraries supporting range of raster and vector formats, as well as projections. GRASS toolkits for Quantum GIS (QGIS) and R Project for Statistical Computing have been developed thanks to strong links with these projects.

The third edition of *Open Source GIS: A GRASS GIS Approach* reflects these new developments. The first chapter includes information about the OSGeo foundation. Chapter three that introduces GRASS and the new sample data set, has added information about the new graphical user interfaces that can be used with GRASS 6. The properties of GRASS raster and vector data are described in chapter four, which also includes extensive material on importing data in various formats, and an introduction to new geocoding tool. The raster chapter has been enhanced with new examples, more comprehensive topographic analysis and modeling, and introduction to voxel data processing. The chapter on vector data has been completely rewritten to reflect introduction of a new vector data format and attribute support through

database management system (DBMS) in GRASS 6. This chapter now includes new sections on attribute database management and SQL support, vector networks analysis, linear reference systems, and lidar data applications. The site data chapter of earlier book editions was integrated within the chapter six as vector point data processing section. The visualization chapter reflects the changes in 2D display, nviz, and use of Paraview. Image processing was reduced and updated, orthophoto chapter was eliminated to make space for more new material. Application chapter was merged with raster analysis. Equations and SQLite-ODBC connection guide were added into Appendix. All chapters were enhanced with numerous practical examples using the first release of a free, comprehensive, state-of-the-art geospatial data set. The examples are based on the GRASS 6.3 version from July 2007.

Finally, we briefly recall history of GRASS and this book: GRASS was developed in 1982-1995 by the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) in Champaign, Illinois to support land management at military installations. After CERL withdrew from further GRASS development in 1995, the GRASS 4.2.1 release, published in 1998, was coordinated by this book's author at the Institute of Physical Geography and Landscape Ecology, University of Hannover. The development of the GRASS 5.0 release started in 1999 when GRASS was released under GPL. Since 2001, the "GRASS Development Team" has its headquarters at FBKITC-irst (Centro per la Ricerca Scientifica e Tecnologica), Trento, Italy. GRASS 5.0.0 was officially released in 2002, accompanied by the first FOSS4G – GRASS users conference held in September 2002 in Trento, Italy, and by the publication of the first edition of this book.

The book has its own history. It started as "GRASS Recipes" written in 1995 for students at the Institute of Landscape Architecture, University of Hannover. In 1996, the first continuous German text was written and later published in "Geosynthesis" series at the Geographical Institute, University of Hannover. The first english edition of the book, published in June 2002, was the result of collaborative work of a number of translators and a new coauthor. It was written for the GRASS 5.0pre3 release. The second edition, published in 2004, was based on the GRASS 5.3 release and included updates reflecting the system enhancements and the feedback from our readers. This third edition is based on GRASS 6 and represents a fundamental update and enhancement of the material.

The GRASS project's Web site, providing access to the GRASS software and documentation, can be reached at "GRASS Headquarters" at `http://grass.itc.it` and a number of mirror sites. The material related to this book can be accessed at `http://grassbook.org`.

Trento, Italy — *Markus Neteler*
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This 3rd edition has been substantially rewritten using a new, modern data set that was prepared thanks to agencies providing public access to geospatial data. We are especially grateful to the North Carolina (NC) Center for Geographic Information and Analysis, Wake County GIS, NC State Climate Office, NC Department of Transportation, and USGS for making their data available. Advice and assistance with the data set by Julia Harrell, Silvia Terziotti, Robert Austin, Adeola Dokun, Jeff Essic, and Doug Newcomb, and computer system assistance by Micah Colon are greatly appreciated.

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