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Methodology for Performing Return-On-Investment (ROI) Studies for Implementation of GRASS on Military Installations

by
Benjamin Sliwinski

The Geographic Resources Analysis Support System (GRASS) is a geographic information and image processing system originally designed to serve land managers and environment planners at Army installations. This report outlines a method for performing Return-On-Investment (ROI) studies for GRASS. An ROI analysis helps to calculate the benefit-to-cost ratio (B/C) as a basis for decisionmaking in acquiring GRASS hardware and software, in evaluating the economies of using GRASS software in new applications, or in verifying actual against projected costs of running GRASS. The ROI methodology as structured in this report is composed of three data sheets with instructions and a final worksheet on which the ROI may be calculated. The first two data sheets help to calculate the cost of data acquisition and input (hardware, software, and labor costs), and data manipulation and output (hardware upgrades, peripherals, labor, and materials). The third data sheet helps to calculate a benefits analysis of the system, and the final calculation worksheet helps to compute a summation of all accrued costs and benefits.

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This report outlines a method for performing Return-On-Investment (ROI) studies for the Geographic Resources Analysis Support System (GRASS). An ROI analysis helps to calculate the benefit-to-cost ratio (B/C) as a basis for decisionmaking in acquiring GRASS hardware and software, in evaluating the economies of using GRASS software in new applications, or in verifying actual against projected costs of running GRASS. This ROI methodology is composed of three data sheets with instructions and a final worksheet on which the ROI may be calculated. The first two data sheets help to calculate the cost of data acquisition and input (hardware, software, and labor costs), and data manipulation and output (hardware upgrades, peripherals, labor, and materials). The third data sheet helps to calculate a benefits analysis of the system, and the final calculation worksheet helps to compute a summation of all accrued costs and benefits.

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FOREWORD

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METHODOLOGY FOR PERFORMING RETURN-ON-INVESTMENT (ROI) STUDIES FOR IMPLEMENTATION OF GRASS ON MILITARY INSTALLATIONS

1 INTRODUCTION

The purpose of this document is to outline a methodology for performing a return-on-investment (ROI) study for the GRASS geographic information system (GIS) computer program. In its simplest form, an ROI seeks to express monetary flows consisting of costs and benefits over the lifetime of a project into a single present worth which can be compared with initial project investments. The value of the ROI can then be compared with those of historically successful projects of a similar nature to arrive at decisions regarding project funding. In the case of GRASS, historical ROI data is not available, so that initially a somewhat arbitrary interpretation of the ROI will be necessary. Later, as this methodology is routinely implemented, an historic basis for decisionmaking can be developed.

In performing an ROI study for the GRASS system, the analyst (or the installation GIS coordinator) must estimate the monetary costs and benefits of two alternatives: obtaining and using GRASS in solving a particular problem, or solving the problem using current methods. These estimates of monetary costs and benefits derive from considerations of such items as: staffing, training, user support, hardware and software costs, data costs, and the life cycle of the project. The intent of the ROI methodology described here is to guide the prospective GRASS user through consideration of these and other factors, and the final present-worth calculation leading to determining an ROI for the user's specific GRASS application.

What Is GRASS?

The Geographic Resources Analysis Support System (GRASS) is a grid cell-based geographic information system (GIS) developed by USACERL, which runs on a variety of minicomputers and PCs. GRASS has been used as a tool for the display, manipulation, analysis, and predictive modeling of data which can be spatially represented. Broadly, this has involved the areas of facility siting, locational prediction of phenomena (archaeological sites, crimes done according to pattern, etc.), and the monitoring of change over time and space (as in the monitoring of erosion, live deer weight, and timber production across an installation). GRASS searches a database for the presence of variables (or combinations of variables) specified by the user, and displays and manipulates the data as requested.

What Is an ROI?

The term return-on-investment (ROI) is meant here as a general measure of the economic value of investing funds in the use of GRASS. This method of determining the ROI is to calculate the benefit-to-cost (B/C) ratio, and should not be confused with other return-on-investment methods such as the Accounting Return-On-Investment (AROI) or the Internal Rate of Return (IRR). The benefit-to-cost ratio has historically been used as a measure of the ROI by USACERL to evaluate the success of research projects, and also (as the savings-to-investment ratio, SIR) in the USACERL-developed Life Cycle Cost In Design (LCCID) economic analysis computer program.

In calculating the ROI as a benefit-to-cost ratio, annual benefits are determined from annual savings which occur due to using GRASS versus some alternative method. These annual benefits, over the lifetime of the GRASS application, are discounted to a single present worth. Likewise, the present worth of the initial investment, plus the discounted annual usage costs, is also determined to complete the benefit-to-cost ratio. This can be expressed as:

$$ROI = \frac{Present\ Worth\ of\ Benefits}{Present\ Worth\ of\ Costs} \qquad \text{[Eq 1]}$$

The present worth of the annually occurring costs and benefits is calculated using the present worth factor p/a given below:

$$p/a = \frac{(1+i)^n - 1}{i(1+i)^n} \qquad \text{[Eq 2]}$$

where n = the project life in years
i = the annual discount rate.

The discount rate is the interest rate used to calculate the present worth of future amounts (either costs or benefits). Whereas we speak of compounding money forward in time, we speak of discounting money backward in time. In calculating a present worth, the interest rate is therefore referred to as the discount rate. An example ROI analysis demonstrating this method is included in Appendix A of this document.

Why Perform GRASS Return-On-Investment Studies?

The ultimate purpose of performing an ROI study for GRASS (or any other activity) is to develop economic information to be used as a basis for decisionmaking. In GRASS implementation, there are a number of situations where it is useful to calculate the ROI in the form of a benefit-to-cost ratio (B/C).

The first situation occurs when it is desired to calculate the projected ROI for acquiring GRASS hardware and software and performing a specific application. In this case, the decision being supported is whether to invest in acquiring and using GRASS or to continue using some existing technique.

The second situation is one in which an installation already is using GRASS hardware and software for one application, and would like to examine the projected ROI of using GRASS for a different application. In this case the decision being supported is whether to expand the use of GRASS to the additional application, or perform the additional application with existing techniques.

Finally, a third situation may occur where an installation has been using GRASS hardware and software for some application (or applications), and would like to determine the actual (i.e., based on actual instead of projected costs and benefits) ROI for this application (or applications). This type of ROI might be used in a number of ways. It could, for example, be compared with earlier projected ROIs for this particular application, to evaluate the accuracy of the projection process; or, it could be used at the major command level in developing a database of ROI data to be used in evaluating the economic viability of future GRASS applications.

The methodology described in this document is applicable to all three of the above types of ROI studies.

General Instructions

The ROI methodology described here is structured as three data sheets with instructions and a final worksheet on which the ROI is calculated. The data sheets and worksheet are:

- Sheet A - Cost Elements for Data Acquisition and Input
- Sheet B - Cost Elements for Data Manipulation and Output
- Sheet C - Benefits Analysis
- Sheet D - ROI Calculation Worksheet.

Each of the three data sheets has separate instructions which follow this section of general instructions. In completing each of the data sheets, the analyst will at times be directed to review various GRASS related references. These references are listed in Table 1 below. It is strongly recommended that the analyst assemble these references before proceeding with completion of the data sheets. All are available from the USACERL GRASS Information Center, 1-800-USA-CERL, x220.

Table 1

GRASS References

Bradshaw, Stuart and Pam Thompson, *Options for Acquiring Elevation Data*, Technical Manuscript N-89/20 (U.S. Army Construction Engineering Research Laboratory [USACERL], January 1989).

Brooks, Douglas, Michael Higgins, and Mark Johnson, *GRASS Hardware Configurations Guide*, ADP Report N-89/21 (USACERL, March 1989).

Goran, William D., *Testing Guidelines for GRASS Ports and Drivers*, ADP Report N-89/22 (USACERL, January 1989).

Johnson, Mark, and William D. Goran, *Sources of Digital Spatial Data for Geographic Information Systems*, Technical Report N-88/01/ADA189788 (USACERL, December 1987).

Ruiz, Marilyn, *Cartographic Issues in Database Development*, Technical Manuscript N-89/24 (USACERL, September 1988).

Westervelt, James, Michael Shapiro, William D. Goran, et al., *GRASS User's Reference Manual*, ADP Report N-87/22 (USACERL, September 1988).*

*Chapters in the *GRASS User's Reference Manual* will be denoted with a "†".

Project/Application Life Cycle

A key factor in determining the ROI is the life cycle of the particular GRASS application. Determination of the application life cycle begins by considering again the purpose of performing an ROI. While in some instances an ROI is performed after the fact, i.e., as a justification of previously expended funds, an ROI in general practice is performed prior to expending funds, as a prudent measure to avoid their misuse. Within this context, for a given GRASS application, the life cycle to be used in the ROI analysis begins with the projected or actual expenditure of any funds, and ends with the projected or actual completion of all activities associated with the GRASS application. In general, it will be assumed that this period will be less than the useful life of the equipment required for the application.

For a given ROI analysis, there can be only one life cycle. If it is desired to evaluate several GRASS applications having different life cycles, a separate analysis should be performed for each application, or the project life cycle should be taken as starting with the beginning of funds expenditure for the earliest application and ending with completion of activities relating to the last application.

Annual Versus One-Time Amounts

In the form of ROI analysis used here, costs and benefits are entered as annual or one-time amounts. For simplicity in this analysis, one-time amounts can occur only in the first year of the life cycle. Therefore, only amounts occurring once and in the first year should be entered as one-time amounts. Any amount occurring more than once, or not occurring in the first year of the life cycle, must be entered as an annual amount. Annual amounts are assumed to begin occurring in the first year of the life cycle and end in the last year of the life cycle. The annual amount is constant throughout the life cycle. If an annual amount is expected to vary over the life cycle, the amount should be averaged to result in a uniform annual amount. Likewise, if a single amount occurs outside of the first year it should be averaged over the life cycle and entered as a uniform annual amount. Finally, amounts may occur which are shared between GRASS and some other activity (for example, a computer running GRASS may also be used for other purposes); the amounts (annual or one-time) entered in this ROI calculation should be based on the percentage usage for GRASS purposes.

2 INSTRUCTIONS FOR COMPLETING SHEET A: COST ELEMENTS FOR DATA ACQUISITION AND INPUT

The heart of the GRASS system is the geographic database; it is therefore not surprising that this cost element can be a significant cost associated with implementation of a specific GRASS application. It is recommended that in preparation of this section of the ROI, the analyst review "GRASS Tutorial: Map Preparation,"† "Cartographic Issues In Database Development,"† and "Sources of Digital Spatial Data For Geographic Information Systems." These documents provide a description of the raster-based data used by GRASS as well as costs and methods associated with acquiring geographic data. Prior to proceeding, the analyst should complete the worksheet below.

1. How large is the land area under consideration (km^2)

2. Assuming the land area is generally rectangular, what are the latitude and longitude (or Northing and Easting in UTM system) of the upper left hand and lower right hand corners of the land area?

Upper L.H. corner lat. (North) = ______ long. (East) = ______
Lower R.H. corner lat. (North) = ______ long. (East) = ______

3. What data resolution is required? The GRASS system uses raster data stored as n x m cells, where n and m are the lengths of the sides of the cell. State, in meters, the smallest value of n or m which you anticipate will be required in your application. (See "Cartographic Issues In Database Development.") Required resolution is meters.

4. What are the attributes (e.g., soil type, vegetation type, elevation, usage, etc.) which each cell must have (other than location) to be useful in this GRASS application? Do not list attributes which can be derived from other attributes. For example, if both "elevation" and "slope" attributes are needed, list only "elevation" here since GRASS can create a slope file from the elevation data. Please list these attributes below, or use another sheet if necessary.

5. What is the life cycle in years for this application? (Not to exceed the expected equipment life.)

You are now ready to estimate costs associated with data acquisition and input. These cost elements may have either annual or one-time cost components; note that separate blanks are provided for these components on Sheet A. Please complete the following lines on Sheet A.

Line 1: Labor to Locate Sources of Geographic Data

Estimate manhours and labor rate to locate appropriate sources of existing hardcopy or digital geographic data. Keep in mind that more than one source may be required to obtain data for all the attributes previously identified. Enter one-time or annual costs separately.

Line 2: Costs for Acquisition of New Geographic Data

If geographic data is unavailable as hardcopy or digital maps, raw data must be collected and hardcopy or digital maps developed. This may require aerial surveys, field surveys by ground crews, and/or review of literature or other data sources. Enter on line 2 the total estimated labor and material cost for gathering new geographic data and compiling into original digital or hardcopy maps. Use the worksheet below to estimate these costs. If this work will be contracted, check the box marked "contracted" (on Sheet A) and enter the estimated contract amount on line 2. Enter one-time or annual costs separately.

	One-Time	Annual
a. Total labor and material costs for aerial surveys	_____	_____
b. Total labor and material costs for field surveys	_____	_____
c. Total labor and material costs for literature review	_____	_____
d. Other (specify)	_____	_____
e. Total (Sum of lines 2a through d) Enter on line 2, Sheet A.	_____	_____

Lines 3a through 3d: Digital Data Costs

Is the source of data in digital format. i.e., magnetic tape or disk? If no, skip to line 4; if yes, indicate the source of digital data here and continue to complete lines 3a to 3d.

3a. Enter on line 3a the estimated cost (material only) to acquire existing digital data. (Do not include costs shown on line 2 for acquisition of new geographic data). Enter one-time or annual costs separately.

3b. Is necessary hardware (tape drive, etc.) available to extract and input this data to GRASS? If no, estimate the cost of acquiring/accessing this hardware on line 3b. Enter one-time or annual costs separately.

3c. Will GRASS software support input of this data? If yes, skip to 3d. If no, estimate manhours and labor rate to develop custom software for data input and enter on line 3c. Enter one-time or annual costs separately.

3d. Estimate manhours and labor rate to use GRASS software or custom software to extract and input digital data into GRASS database and enter on line 3d. Enter one-time and annual costs separately.

Lines 4a through 4f: Hardcopy Data Costs

If all digital data is unavailable, hardcopy maps must be digitized or scanned and the data entered into the GRASS database. Keep in mind that a separate map may be required for each of the attributes previously identified. Indicate the anticipated sources of map data here and complete lines 4a through 4f.

4a. Estimate the costs (material only) of obtaining these maps and enter on line 4a. (Do not include costs shown on line 2 for acquisition of new geographic data) Enter one-time or annual costs separately.

4b. Often maps must be redrawn prior to being digitized. Estimate the manhours and labor rate required to redraft maps as necessary and enter on line 4b. If this work will be contracted, check the box marked "contracted" and enter the estimated contract cost. Enter one-time or annual costs separately.

4c. Is digitizing hardware available? If not, estimate the cost of this digitizing hardware and enter on line 4c. (See "GRASS Hardware Configuration Guide" for approximate costs.) If instead of purchasing digitizer hardware, it is decided to contract for map digitization, check the box marked "contracted," enter the estimated contract amount on line 4c, and then skip to line 4f. Enter one-time or annual costs separately.

4d. Are trained personnel available to perform map digitization? If no, enter on line 4d the estimated cost for training digitizer personnel. Enter one-time or annual costs separately.

4e. Estimate the manhours and labor rate for trained personnel to digitize map data and enter the estimate on line 4e. Enter one-time or annual costs separately.

4f. Estimate the manhours and labor rate to input the digitized map data into GRASS using GRASS software and enter on line 4f. Enter one-time or annual costs separately.

Line 5a: Total One-Time Costs

Total of lines 1 through 4, one-time costs only.

Line 5b: Total Annual Costs

Total of lines 1 through 4, annual costs only.

3 SHEET A: COST ELEMENTS FOR DATA ACQUISITION AND INPUT

Item	Description				One-Time	Annual
1.	Labor to locate sources of geographic data	______ manhours	x ______ rate	=	______	
		______ manhours	x ______ rate	=		______
2.	Costs for acquisition of new geographic data ☐ Contracted			=	______	______
3a.	Material cost for digital data			=	______	______
3b.	Hardware to read digital data (tape or disk drive)			=	______	______
3c.	Labor to develop custom software to input data	______ manhours	x ______ rate	=	______	
		______ manhours	x ______ rate	=		______
3d.	Labor to input data using GRASS or custom software	______ manhours	x ______ rate	=	______	
		______ manhours	x ______ rate	=		______
4a.	Material cost for hardcopy map data			=	______	______
4b.	Labor to redraft hardcopy maps as necessary ☐ Contracted	______ manhours	x ______ rate	=	______	
		______ manhours	x ______ rate	=		______
4c.	Hardware costs for digitizing data	☐ Contracted (skip to 4f)		=	______	______
4d.	Training costs to train digitizer personnel			=	______	______
4e.	Labor for digitizing map data	______ manhours	x ______ rate	=	______	
		______ manhours	x ______ rate	=		______
4f.	Labor to input digitized data into GRASS	______ manhours	x ______ rate	=	______	
		______ manhours	x ______ rate	=		______
5a.	Total one-time costs for data acquisition and input (Sum of lines 1 to 4, one-time costs only)			=	______	
5b.	Total annual costs for data acquisition and input (Sum of lines 1 to 4, annual costs only)			=		______

4 INSTRUCTIONS FOR COMPLETING SHEET B: COST ELEMENTS FOR DATA MANIPULATION AND OUTPUT

GRASS allows users to manipulate geographic data to produce useful output for various applications. The GRASS system capabilities can be broadly classified into four categories:

- Data Input
- Image Processing
- Geographic Analysis
- Map Display

The data input aspect will not be discussed here since costs related to data input and acquisition were evaluated in the previous section. In preparing this portion of the ROI, the analyst should review "An Introduction to GRASS"† and become familiar with the GRASS capabilities listed above. Below, we will examine hardware and software costs, and labor and materials costs, for data manipulation and output.

Hardware and Software Costs

Since data manipulation is one of the primary uses of the GRASS system, the overall hardware and software requirements and costs (other than those discussed under data input), will be identified in this section. In preparing this section of the ROI it is recommended that the analyst review the "GRASS Hardware Configuration Guide."† This document lists minimum hardware specifications needed to run GRASS, and includes cost data for computers, digitizers, and printers used in running GRASS.

Complete the following lines on Sheet B in order to estimate hardware and software costs associated with GRASS implementation. Unless otherwise indicated, these costs are assumed to be one-time costs occurring in the first project year.

Line 1: Acquiring GRASS Software

GRASS software is available from the USACERL GRASS Support Center and from commercial distributors. Estimate the cost for acquiring GRASS software and enter on line 1.

Lines 2a through 2i: Upgrade Existing Computer

GRASS requires a computer running UNIX or a similar operating system. If such a computer is currently available and is being considered for use in the prospective GRASS application, please complete lines 2a through 2i. If no computer is currently available please skip to line 3.

2a. Does the computer have a graphics library such as GKS or SIGCORE? If no, enter cost for graphics library software on line 2a.

2b. Does the computer have at least 4 megabytes of memory? Will the computer support upgrade to 4 megabytes? If no, skip to line 3, otherwise enter cost of memory upgrade on line 2b.

2c. If the computer does not have a 256-color-capable monitor, enter this monitor cost on line 2c.

2d. Usually, a color monitor is required for graphics while a second monitor is required for entering GRASS commands. If two monitors are not available, enter the cost for a second monitor on line 2d.

2e. Does the computer system have a mouse pointing device? If no, enter cost of mouse and mouse software on line 2e.

2f. A 300 megabyte hard disk drive is recommended as a minimum. If the computer does not presently have a drive of at least this capacity, enter the cost of a hard disk upgrade on line 2f.

2g. Access to a tape drive is required for data backup. If a 1/2 inch tape drive was estimated under data input, enter zero; otherwise, enter on line 2g the cost of a 1/2 or 1/4 inch drive.

2h. A text printer is required for text output. If the present computer does not have a text printer, enter the cost for a text printer on line 2h.

2i. Enter the total cost (sum lines 2a through 2h) for upgrade of existing computer on line 2i.

Line 3: Acquiring New Computer

If a computer is to be purchased for the GRASS application, it must be UNIX compatible and have other important characteristics. The "GRASS Hardware Configuration Guide"† should be reviewed to determine minimum machine requirements. This reference provides cost information for several configurations meeting these minimum requirements. These costs are also included in Appendix B. Please select the configuration most likely to be used in the prospective application and enter the cost on line 3. If a system will be configured from scratch please check the box marked "other" and enter the cost on line 3.

Line 4: Peripherals and Enhancements

In addition to the basic hardware configuration, some applications may benefit from additional peripherals and performance enhancement options. In particular, the printing of maps will require that you have a high quality multicolor printer. Please estimate the costs for any additional options which may be necessary for your particular application using the worksheet below. (Refer to the "GRASS Hardware Configuration Guide" for specifications and estimated costs.) Enter the total costs for peripherals and enhancements on line 4 Sheet B.

a. Color graphics printer ______

b. Additional system memory ______

c. Floating point processor ______

d. Other ______

e. Total cost for peripherals and enhancements (sum lines 4a through d) ______

Line 5: Hardware Maintenance Contract

It is recommended that a hardware maintenance contract be obtained for the computer system. Please estimate the annual cost for this maintenance contract on line 5.

Line 6: Modifications to Existing Facilities

The computer system may require modifications to existing facilities such as air conditioning, uninterrupted power supply, or power conditioning. The specific modifications needed should be determined through review of the power and environmental control requirements of the computer under consideration. Please estimate the costs of these modifications if required and enter on line 6.

Labor and Material Costs

Labor costs for data manipulation are estimated on an annual basis. It is assumed that these costs will recur throughout the life of the particular GRASS application. While each GRASS application is different, there are certain generic data manipulation tasks which are common to analysis of geographic data. These are:

- Data development/input
- Map generation/output
- Inventory of attributes
- Proximity analysis
- Prediction of occurrence of attributes

Costs associated with data development and input have been estimated in a previous section and will not be considered here. Hardware costs for map generation have been identified in the hardware portion of this section. Labor and material (supplies) for this activity (map generation) and the others listed will be developed below.

Line 7: Training of Personnel to Manipulate Data

Data manipulation using the GRASS data system is a moderately complex skill requiring a certain degree of operator training and familiarity with both UNIX and GRASS. The costs for this training may occur as an annual cost or as a one-time cost during the first project year. Enter the estimated training cost on line 7. Enter one-time or annual costs separately.

Line 8: Map Generation

A major activity in geographic analysis is the generation of maps displaying various attributes of a geographic area. With GRASS, it is possible to "overlay" maps of various attributes (such as soil type and elevation) to generate a third map indicating, for example, areas in which conducting an activity such as training might be suitable. Using the worksheet below, estimate the total annual costs for map generation and enter on line 8.

a. Estimate the number of maps to be generated annually ______

b. Estimate the annual material costs for map generation (See "GRASS Tutorial: Map Preparation"†) ______

c. Estimate the annual labor costs for map generation ______ x ______ = ______
manhours rate

d. Total annual costs for map generation (sum lines b through c) ______

Line 9: Inventory of Attributes

Another important geographic analysis activity is performing an inventory of areas having a certain attribute (such as soil type, vegetation type, elevation, etc.). Estimate the manhours and labor cost for this activity, and enter the result on line 9. *It may be helpful to review the list of attributes previously* developed in the preparation of Sheet A of the analysis.

Line 10: Proximity Analysis

An activity related to inventory of attributes is proximity analysis. Such an analysis examines the relative location of areas having specific attributes with respect to areas having other attributes, for example, the number of parks or wildlife areas located within some specified distance of the site of a proposed power plant. Enter the estimated annual manhours and labor rate for this activity on line 10.

Line 11: Prediction of Occurrence of Attributes

In some cases, the potential existence of an attribute such as oil- or water-bearing strata, or the existence of an archeological site, can be inferred from the simultaneous occurrence of other attributes at a particular location. The ability to predict the presence of such sites by combining map overlays with logical criteria is an important GRASS capability. Estimate the annual manhours and labor rate for this activity and enter on line 11.

Data Sheet B Totals

Line 12: Total One-Time Costs

Total of one-time costs on lines 1, 2i, and 3 through 11.

Line 13: Total Annual Costs

Total of annual costs on lines 1 through 11.

5 SHEET B: COST ELEMENTS FOR DATA MANIPULATION AND OUTPUT

Hardware and Software Elements	One-Time	Annual
1. Cost for acquiring GRASS software	______	
2. Costs to upgrade an existing computer		
a. Cost for graphics library software	______	
b. Cost for memory upgrade	______	
c. Cost for color monitor	______	
d. Cost for second monitor for command input	______	
e. Cost for mouse and mouse software	______	
f. Cost for hard disk upgrade	______	
g. Cost for tape drive	______	
h. Cost for text printer	______	
i. Total cost for computer upgrade (sum lines 2a through h)	______	
3. Cost of new computer based on Appendix B, or ☐ other.	______	
4. Total costs for peripherals and enhancements	______	
5. Annual cost for hardware maintenance contract		______
6. Costs for modifications to facilities' labor and material	______	
Labor and Materials		
7. Annual or one-time training costs for GRASS applications operators	______	______
8. Annual labor and material costs for map generation		______
9. Annual labor costs for inventory of attributes		______
10. Annual labor costs for proximity analysis		______
11. Annual labor costs for prediction of occurrence of attributes		______
Data Sheet A Totals		
12. Total one-time costs (sum lines 1, 2i, and 3 through 11) (one-time costs only)	______	
13. Total annual costs (sum lines 1 to 11, annual costs only)		______

6 INSTRUCTIONS FOR COMPLETING SHEET C: BENEFITS ANALYSIS

Benefits from utilizing GRASS for a specific application can accrue through savings in labor and materials and in cost avoidance through more accurate or wider scale completion of a specific task. Benefits can also accrue from cost avoidance due to performing tasks which might otherwise not be performed at all. Because of the wide variety of potential GRASS applications and the differing degrees of detailed data necessary to estimate benefits, it is not practical to provide a procedure for estimating benefits for each specific application. Instead, a framework will be presented which identifies those elements likely to be common to most GRASS applications. The analyst should be aware that completion of certain of these elements may require a "best estimate" where complete engineering or scientific data are unavailable.

The benefits elements to be estimated are broken into two categories: those due to savings from improved methods of performing activities related to a specific application, and those due to cost avoidance occurring as the result of completing these activities. This distinction will become clearer as the analysis proceeds.

Benefits from Performing Activities

The activities below are those which are considered generally to be part of tasks to which GRASS may be applicable. For each of these activities we seek to determine if there is a monetary benefit associated with using GRASS. This is done by comparing costs associated with using GRASS for a particular application with those of the existing procedure.

Line 1: Data Development/Input

It is assumed that both GRASS and existing methods require the gathering and input of geographical data. For this element we must compare costs of gathering and input of data using GRASS with costs for gathering equivalent data using existing methods. GRASS may provide significant benefits by allowing the use of satellite data or other data which has been digitized. Use the worksheet below to estimate the annual benefits of using GRASS in this application and enter the result on line 1 of Sheet C.

a. Estimated annual labor and materials cost of existing method. Include all costs such as field surveys, aerial surveys, telephone calls, literature review, etc. ______

b. Estimated annual labor and materials cost using GRASS (from line 5b, Sheet A) ______

c. Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included in line 5b, Sheet A.) ______

Line 2: Map Generation/Output

Both GRASS and existing methods may be required to generate graphic output in the form of maps for analysis purposes and for reporting requirements. The cost of generating and printing these maps may be considerably lower using GRASS, particularly when map synthesis is required (for example, when taking maps of soil and vegetation type and producing a third map indicating suitable training areas). Use the worksheet below to estimate the benefits of applying GRASS in this application here, and enter the results on line 2 of Sheet C.

a. Estimated annual labor and materials cost of existing method ______

b. Estimated annual labor and materials cost using GRASS (from line 8, Sheet B) ______

c. Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included in line 8, Sheet B.) ______

Line 3: Inventory of Attributes

In general, a geographic area will have certain attributes such as soil type, elevation, vegetation type, and others. Often a common requirement is to inventory some particular attribute or combination of attributes. As a computerized system, GRASS can offer substantial advantages in accurately determining such inventories. Remember that the inventory is the act of counting the attribute and, as such, is distinct from the data-gathering activity. Do not include any costs for data gathering here. Estimate the benefits of using GRASS for this application and enter the results on line 3, Sheet C.

a. Estimated annual labor and materials cost of existing method of attribute inventory. Do not include material costs shown under map generation on line 2a, or data-gathering costs shown on line 1a, Sheet C Instructions. ______

b. Estimated annual labor and materials cost using GRASS (line 9, Sheet B) ______

c. Estimated annual benefit, subtract line b from line a; if negative enter zero. (Zero is entered because negative benefits are costs already included in line 9, Sheet B.) ______

Line 4: Proximity Analysis

Another general characteristic of a geographic area is that different attributes (such as streams or parks or recreation areas) will be located in some proximity to other attributes (such as roads or training areas or power plants). Often it is required to assess the number of cases where a certain attribute (or combination of attributes) is within a certain proximity to another attribute (or combination of attributes). Here again, a, a computerized system, GRASS may offer considerable advantages in quickly and accurately identifying and inventorying such relationships. Remember that the act of determining the proximity of attributes is distinct from data gathering. Do not include data-gathering costs here. Estimate the benefits of using GRASS in this application here, and enter the result on line 4, Sheet C.

a. Estimated annual labor and materials cost of existing method of proximity analysis. Do not include material costs shown under map generation on line 2a, or data-gathering costs shown on line 1a, Sheet C Instructions. ______

b. Estimated annual labor and materials cost using GRASS (from line 10, Sheet B) ______

c. Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included on line 10, Sheet B.) ______

Line 5: Prediction of Occurrence of Attributes

In some cases, the potential existence of some attribute such as oil- or water-bearing strata, archeological sites, or diseased vegetation can be inferred from the simultaneous occurrence of other attributes at a particular location. The ability to predict the presence of such sites by combining map overlays with logical criteria is a strong capability provided by the GRASS system. Do not include data-gathering costs here. Use the worksheet below to estimate the benefits of using GRASS in this application and enter the result on line 5, Sheet C.

a. Estimated annual labor and materials cost of existing method to predict occurrence of attributes. Do not include material costs shown under map generation on line 2a, or data-gathering cost shown on line 1a, Sheet C Instructions. ______

b. Estimated annual labor and materials cost using GRASS (from line 11, Sheet B) ______

c. Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included on line 11, Sheet B.) ______

Benefits From Cost Avoidance

The elements of cost avoidance below are those which might occur due to careful analysis of geographic data. The best judgement of the analyst should be used in estimating the magnitude of the benefits likely to occur due to using GRASS in a particular application. Whenever possible, the analyst should rely on accurate engineering or scientific data. Any worksheets and/or calculations used to estimate the benefits below should be attached to Sheet C.

Line 6: Prevention of Attribute Damage On Post

Often the analysis of geographic data is intended to be used to mitigate damage to some geographic attribute such as vegetation or soils. The degree to which damage is prevented may be related to the effectiveness and capabilities of the geographic analysis technique applied. Monetary benefits may be estimated by considering the cost to recondition an attribute to its previous state; to acquire other similar resources; or, as the value lost through inability to use the damaged resource. Estimate the annual monetary benefits of using GRASS in this application to prevent on-post attribute damage, and enter on line 6, Sheet C.

Line 7: Prevention of Attribute Damage Off Post

Deterioration of some geographic attribute by military activities may not be limited to the military installation. Effective management of geographic data may result in reduced damages to off-post attributes with corresponding monetary benefits. Estimate the annual monetary benefits of using GRASS in this application to prevent damage to off-post attributes (resources) and enter on line 7, Sheet C. Estimate monetary benefits using one of the methods described in the previous paragraph ("Line 6: Prevention of Attribute Damage On Post").

Line 8: Prevention of Environmental Damage Other Than Discussed In Lines 6 and 7

Some environmental characteristics such as air and water quality may not be represented strictly as geographic attributes but may nonetheless be impacted by effective geographic analysis. Estimate the annual monetary benefits of using GRASS in this application to prevent other environmental damage, and enter on line 8, Sheet C. Estimate monetary benefits using one of the methods described above in the paragraph ("Line 6: Prevention of Attribute Damage On Post").

Line 9: Enhancement of Mission Performance

An important area likely to be affected by geographic analysis is mission performance. Improvements in performance may occur through more effective training, reduction in accidents, reduction in vehicle maintenance, reduced frequency of inspection and surveys, and other similar items. Estimate the monetary benefits of using GRASS in this application to enhance mission performance, and enter on line 9, Sheet C.

Data Sheet C Totals

Line 10: Total Benefits from Performing Activities

Total benefits from activities which result from the use of GRASS, sum lines 1 through 5, above.

Line 11: Total Benefits from Cost Avoidance

Total benefits from cost avoidance which result from the use of GRASS, sum lines 6 through 9, above.

7 SHEET C: BENEFITS ANALYSIS

Activities	Annual
1. Annual benefit in using GRASS for data development/input	______
2. Annual benefit in using GRASS for map generation/output	______
3. Annual benefit in using GRASS to inventory attributes	______
4. Annual benefit in using GRASS for proximity analysis	______
5. Annual benefit in using GRASS to predict occurrence of attributes	______
Cost Avoidance	
6. Prevention of attribute damage on post	______
7. Prevention of attribute damage off post	______
8. Prevention of environmental damage other than items 6 and 7	______
9. Enhancement of mission performance	______
Data Sheet C Totals	
10. Total annual benefits from activities (sum 1-5)	______
11. Total annual benefits from cost avoidance (sum 6-9)	______

8 SHEET D: ROI CALCULATION WORKSHEET

One-Time Costs

1. Data acquisition and input; enter from line 5a, Sheet A ________
2. Data manipulation and output; enter from line 12, Sheet B ________
3. Total one-time costs (sum 1 and 2) Annual Costs ________

Annual Costs

4. Data acquisition and input; enter from line 5b, Sheet A ________
5. Data manipulation and output; enter from line 13, Sheet B ________
6. Total annual costs (sum 4 and 5) Annual Benefits ________

Annual Benefits

7. Benefits from activities; enter from line 10, Sheet C ________
8. Benefits from cost avoidance; enter from line 11, Sheet C ________
9. Total annual benefits (sum 7 and 8) Present Worth Factor (p/a) ________

Present Worth (p/a)

10. Enter project/application life in years n = ________
11. Enter discount rate as fraction (i.e., 10% = .10) (OMB Circular A-94 uses 10% discount rate) i = ________
12. Calculate present worth factor p/a using the equation below or use the attached table for i = .10, and enter result on line 12

$$p/a = \frac{(1 + i)n - 1}{i(1 + i)n}$$

p/a = ________

ROI Calculation

13. Enter total one-time cost from line 3 above ________
14. Multiply total annual costs on line 6 by present worth factor on line 12 and enter the result on line 14 ________
15. PRESENT WORTH OF COSTS (sum 13 and 14) ________
16. PRESENT WORTH OF BENEFITS, multiply total annual benefits on line 9 by present worth factor on line 12, and enter on line 16 ________
17. ROI, Present Worth of Benefits/Present Worth of Costs, divide line 16 by line 15, and enter result on line 17 ________

APPENDIX:

EXAMPLE OF HYPOTHETICAL GRASS ROI CALCULATION

Present Situation

Fort Southern, AL, has 25,600 acres of pine forest. This forest provides excellent terrain for certain kinds of training as well as having esthetic and economic value (some commercial logging is permitted at Fort Southern). A major problem in managing these forested acres is controlling infestation by the "dreaded pine beetle."

Current practice is to remove and destroy badly infested trees and apply insecticide to lightly infested trees. It is estimated that the cost of removing a tree is $100/tree, while applying insecticide is estimated to cost $10/tree. Last year, 500 trees were sprayed at a cost of $5000 and 200 trees were removed at a cost of $20,000.

Inspection for infested trees is carried out by a number of means including aerial surveys. Satellite data was not utilized. The annual cost for these inspections is estimated at $1/acre or $25,600 per year.

An additional factor is that Fort Southern is bordered on the northwest by 10 miles of commercial forest lands. These commercial interests have become concerned with the government's management of the pine beetle to the extent that the government has agreed to compensate these commercial interests for timber damaged by pine beetle infestation shown to originate on installation property. (A reciprocal agreement also exists.) It is estimated that government liability under this agreement could be as high as $25,000 per year.

Proposed GRASS Application

It is proposed that using GRASS, multispectral satellite data can be used to locate infested trees at Fort Southern, and identify the spreading of infestations. Potential advantages of this technique would be a reduction in annual inspection costs and the ability to locate trees while only lightly infested. By locating trees with only light infestations, or those which lie in the path of the infestation, it is hoped that spraying can be applied to avoid the need for tree removal. The ability to locate lightly infested trees is also expected to reduce the government's potential liability for damage to commercial forest lands.

Cost/Benefit Analysis

The completed sheets A, B, C, and D for this hypothetical GRASS application are included below.

EXAMPLE SHEET A: COST ELEMENTS FOR DATA ACQUISITION AND INPUT

No.	Cost element	Manhours		Rate		One-Time	Annual
1.	Labor to locate sources of geographic data	20 manhours	x	25 rate	=	500	
		manhours	x	rate	=		
2.	Costs for acquisition of new geographic data ☐ Contracted				=		
3a.	Material cost for digital data *(SPOT Satellite, 1-Multispectral Scene)*				=		1700
3b.	Hardware to read digital data (<u>tape</u> or disk drive)				=	10,000	
3c.	Labor to develop custom software to input data	manhours	x	rate	=	0	
		manhours	x	rate	=		
3d.	Labor to input data using GRASS or custom software	manhours	x	rate	=		
		5 manhours		25 rate	=		125
4a.	Material cost for hardcopy map data *(USGS quads)*				=	10	
4b.	Labor to redraft hardcopy maps as necessary ☐ Contracted *(2 maps: [1] installation & training areas [2] area of installation and neighboring commercial forest)*	200 manhours	x	25 rate	=	5,000	
		manhours	x	rate	=		
4c.	Hardware costs for digitizing data	☐ Contracted (skip to 4f)			=	1,500	
4d.	Training costs to train digitizer personnel				=	0	
4e.	Labor for digitizing map data	manhours	x	rate	=	0	
		manhours	x	rate	=		
4f.	Labor to input digitized data into GRASS	10 manhours	x	25 rate	=	250	
		manhours	x	rate	=		
5a.	Total one-time costs for data acquisition and input (Sum of lines 1 to 4, one-time costs only)				=	17,260	
5b.	Total annual costs for data acquisition and input (Sum of lines 1 to 4, annual costs only)				=		1,825

EXAMPLE SHEET B: COST ELEMENTS FOR DATA MANIPULATION AND OUTPUT

Hardware and Software	One-Time	Annual
1. Cost for acquiring GRASS software	500	
2. Costs to upgrade an existing computer		
a. Cost for graphics library software		
b. Cost for memory upgrade		
c. Cost for color monitor		
d. Cost for second monitor for command input		
e. Cost for mouse and mouse software		
f. Cost for hard disk upgrade		
g. Cost for tape drive		
h. Cost for text printer		
i. Total cost for computer upgrade (sum lines 2a through h)	0	
3. Cost of new computer based on Appendix B, or ☐ other. *(Masscomp Config #1)*	23,920	
4. Total costs for peripherals and enhancements *(printer LQ2500)*	1,599	
5. Annual cost for hardware maintenance contract		1,000
6. Costs for modifications to facilities labor and material	400	
Labor and Material		
7. Annual or one-time training costs for GRASS applications operators		
8. Annual labor and material costs for map generation		1,150
9. Annual labor costs for inventory of attributes *(8h @ $25/h)*		200
10. Annual labor costs for proximity analysis		200
11. Annual labor costs for prediction of occurrence of attributes *(40h @ $25/h)*		1,000
Data Sheet Totals		
12. Total one-time costs (sum lines 1, 2i, and 3 through 11) (One-time costs only)	24,419	
13. Total annual costs (sum lines 1 to 11, annual costs only)		3,550

EXAMPLE INSTRUCTIONS FOR COMPLETING SHEET C: BENEFITS ANALYSIS

Benefits From Performing Activities

Line 1: Data Development/Input

It is assumed that both GRASS and existing methods require the gathering and input of geographical data. For this element we must compare costs of gathering and input of data using GRASS with costs for gathering equivalent data using existing methods. GRASS may provide significant benefits by allowing the use of satellite data or other data which has been digitized. Use the worksheet below to estimate the annual benefits of using GRASS in this application and enter the result on line 1, Sheet C.

a.	Estimated annual labor and materials cost of existing method. Include all costs such as field surveys, aerial surveys, telephone calls, literature review, etc.	25,600
b.	Estimated annual labor and materials cost using GRASS (from line 5b, Sheet A)	1,825
c.	Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included in line 5b, Sheet A.)	23,775

Line 2: Map Generation/Output

Both GRASS and existing methods may be required to generate graphic output in the form of maps for analysis purposes and for reporting requirements. The cost of generating and printing these maps may be considerably lower using GRASS, particularly when map synthesis is required (for example, when taking maps of soil and vegetation type and producing a third map indicating suitable training areas). Use the worksheet below to estimate the benefits of using GRASS in this application and enter the result on line 2, Sheet C.

a.	Estimated annual labor and materials cost of existing method	2,000
b.	Estimated annual labor and materials cost using GRASS (from line 8, Sheet B)	1,150
c.	Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included in line 8, Sheet B.)	850

Line 3: Inventory of Attributes

In general, a geographic area will have certain attributes such as soil type, elevation, vegetation type, and others. Often a common requirement is to inventory some particular attribute or combination of attributes. As a computerized system, GRASS can offer substantial advantages in accurately determining as such, is distinct from the data-gathering activity. Do not include any costs for data gathering here. Use the worksheet below to estimate the benefits of using GRASS for this application and enter the results on line 3, Sheet C.

a.	Estimated annual labor and materials cost of existing method of attribute inventory. Do not include material costs shown under map generation on line 2a, or data-gathering costs shown on line 1a, Sheet C Instructions.	2,000
b.	Estimated annual labor and materials cost using GRASS (from line 9, Sheet B)	200
c.	Estimated annual benefit, subtract line b from line a; if negative enter zero. (Zero is entered because negative benefits are costs already included in line 9, Sheet B)	1,800

Line 4: Proximity Analysis

Another general characteristic of a geographic area is that different attributes (such as streams or parks or recreation areas) will be located in some proximity to other attributes (such as roads or training areas or power plants). Often it is required to assess the number of cases where a certain attribute (or combination of attributes) is within a certain proximity to another attribute (or combination of attributes). Here again, as a computerized system, GRASS may offer considerable advantages in quickly and accurately identifying and inventorying such relationships. Remember that the act of determining the proximity of attributes is distinct from data gathering. Do not include data-gathering costs here. Use the worksheet below to estimate the benefits of using GRASS in this application and enter the result on line 4, Sheet C.

a.	Estimated annual labor and materials cost of existing method of proximity analysis. Do not include material costs shown under map generation on line 2a, or data-gathering costs shown on line 1a, Sheet C Instructions.	1,000
b.	Estimated annual labor and materials cost using GRASS (from line 10, Sheet B)	200
c.	Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included on line 10, Sheet B)	800

Line 5: Prediction of Occurrence of Attributes

In some cases, the potential existence of some attribute such as oil- or water-bearing strata, archeological sites, or diseased vegetation can be inferred from the simultaneous occurrence of other attributes at a particular location. The ability to predict the presence of such sites by combining map overlays with logical criteria is a strong capability provided by the GRASS system. Do not include data-gathering costs here. Use the worksheet below to estimate the benefits of using GRASS in this application and enter the result on line 5, Sheet C.

a.	Estimated annual labor and materials cost of existing method to predict occurrence of attributes. Do not include material costs	0

shown under map generation on line 2a, or data-gathering cost shown on line 1a, Sheet C Instructions.

b. Estimated annual labor and materials cost using GRASS (from line 11, Sheet B) 1,000

c. Estimated annual benefit, subtract line b from line a; if negative, enter zero. (Zero is entered because negative benefits are costs already included on line 11, Sheet B) 0

EXAMPLE SHEET C: BENEFITS ANALYSIS

Activities	**Annual**
1. Annual benefit in using GRASS for data development/input	23,775
2. Annual benefit in using GRASS for map generation/output	850
3. Annual benefit in using GRASS to inventory attributes	1,800
4. Annual benefit in using GRASS for proximity analysis	800
5. Annual benefit in using GRASS to predict occurrence of attributes *(Presently no predictive efforts)*	0
Cost Avoidance	
6. Prevention of attribute damage on post *(Presently, 500 trees sprayed @ $10/tree; 200 removed @ $100/tree = $25,000/yr* *Estimate using GRASS, 600 trees sprayed; 100 removed = $16,000/yr* *Savings = $ 9,000/yr*	9,000
7. Prevention of attribute damage off post *(Estimate 20% reduction in government liability for commercial forest damage)*	5,000
8. Prevention of environmental damage other than items 6 and 7	
9. Enhancement of mission performance	
Data Sheet Totals	
10. Total annual benefits from activities (sum 1-5)	27,255
11. Total annual benefits from cost avoidance (sum 6-9)	14,000

EXAMPLE SHEET D: ROI CALCULATION WORKSHEET

One-Time Costs

1.	Data acquisition and input; enter from line 5a, Sheet A	17,260
2.	Data manipulation and output; enter from line 12, Sheet B	27,419
3.	Total one-time costs (sum 1 and 2) Annual Costs	44,679

Annual Costs

4.	Data acquisition and input; enter from line 5b, Sheet A	1,825
5.	Data manipulation and output; enter from line 13, Sheet B	3,550
6.	Total annual costs (sum 4 and 5) Annual Benefits	5,375

Annual Benefits

7.	Benefits from activities; enter from line 10, Sheet C	27,255
8.	Benefits from cost avoidance; enter from line 11, Sheet C	14,000
9.	Total annual benefits (sum 7 and 8) Present Worth Factor (p/a)	41,255

Present Worth (p/a)

10. Enter project/application life in years — n = 10

11. Enter discount rate as fraction (i.e. 10% = .10) (OMB Circular A-94 uses 10% discount rate) — i = .10

12. Calculate present worth factor p/a using the equation below, or use the attached table for i = .10, enter result on line 12.

$$p/a = \frac{(1 + i)n - 1}{i(1 + i)n}$$

p/a = 6.145

ROI Calculation

13.	Enter total one-time cost from line 3 above	44,679
14.	Multiply total annual costs on line present worth factor on line 12, enter the result on line 14.	33,029
15.	Present Worth of Costs (sum 13 and 14)	77,708
16.	Present Worth of Benefits, multiply total annual benefits on line 9 by present worth factor on line 12 and enter on line 16.	153,512
17.	ROI, Present Worth of Benefits/Present Worth of Costs, divide line 16 by line 15, and enter result on line 17.	3.26

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