



ArcFVS - An Integration of Geographic Information Systems and Forest Vegetation Simulator

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Abstract

This paper presents the design and implementation of an integrated application called ArcFVS that links the Forest Vegetation Simulator (FVS) and a GIS. FVS is the simulation system chosen for forests in the Upper Wabash river basin by two research projects in the Department of Forestry and Natural Resources at Purdue University. ArcFVS allows to: select spatially or by attribute the forest plots to be projected by FVS, create the FVS input files for the selected plots and display in a geospatial environment different types of FVS output (FVS output files, tables with variables of interest and visualization image files). These functionalities are tested and demonstrated using FIA and newly collected field data from the Upper Wabash region. ArcFVS is designed using ESRI ArcGIS software and VBA programming environment for manipulating ArcObjects. Advantages of ArcFVS include the new GIS capabilities, enhanced format translation functions and the standardized programming environment.

Outline

- Introduction
- Literature review
- Methods
- System development
- Conclusions

Introduction

- FVS is selected as a decision tool to simulate the temporal dynamics of the stands under different management scenarios.
- The spatial component and a GIS would allow the study of the forest spatial dynamics and the spatial relationships between stands and between forest areas and the other surrounding habitats.
- There is one extension of FVS, FVS-EMAP, that can import and display FVS output variables in ESRI's ArcView GIS.
- ArcFVS: an application that improves the GIS-FVS integration at multiple levels.
- There is a need to develop ArcFVS for research projects in the Upper Wabash Basin.

Objectives

- To make it possible to select stands for simulations with spatially-explicit criteria by incorporating spatial components of forests into FVS.
- To offer an automated translation of the inventory files to FVS and Suppose input files.
- To facilitate spatial analysis of FVS outputs by developing an interactive interface between GIS software and FVS simulations.
- To provide FVS users with state-of-the-art GIS tools by using the emerging GIS technology offered by ESRI.
- To support easy update of the GIS-FVS interface by using the standard programming language Visual Basic for Applications (VBA).

1. Literature review

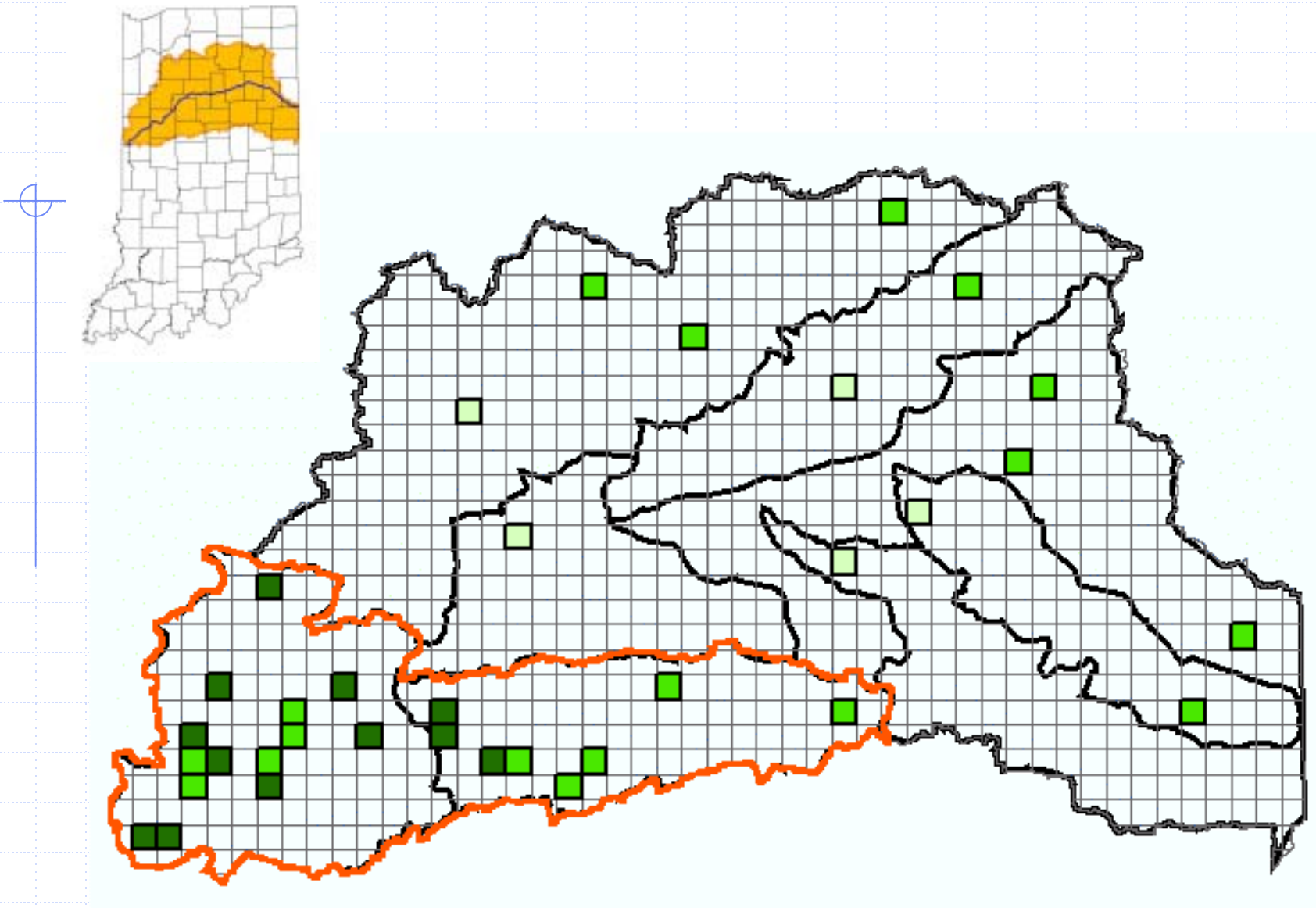
- Research Background
- Forest characterization
- Forest modeling and FVS
- Forest Inventory and Analysis (FIA) database
- Existing GIS tool for FVS

Research background

The ECASE and IFAFS projects:

- Object of study is the Upper Wabash River basin in Northern Indiana. (IFAFS project just two watersheds of the eight 8-digit watersheds).
- Data collection methods are similar: mammal, bird, amphibian, reptile, and plant data are collected using a unified stratified sampling procedure designed to encompass the variety of the landscape.
- The inventory is done using a 10x30 m plot, all trees within the plot being recorded.
- The tree attributes of interest are species and DBH (inches) for trees with at least 5 cm diameter.
- The recorded stand attributes of interest are slope and aspect.

Chivoiu, Bogdan, Swihart, Robert K., and Shao, Guofan. 2001. Developing Objective Methods for Selecting Study Sites Using GIS: An Example from the Upper Wabash River Basin. Graduate Research Symposium 2001, Department of Forestry and Natural Resources, Purdue University.



The study areas for the two projects (in red for IFAFS) and the selected 3-mile cells to be sampled (from light green in 2001 to dark green in 2003)

Forest characterization

- The landscape in the Upper Wabash region is dominated by agricultural land (88%).
- The forest habitat is highly fragmented and the ownership of forestland is mostly private.
- The degree of fragmentation, the predominance of farmland surrounding the forest patches and the management decisions of private owners regarding their forests have a great influence on forest multiple values.

Forest modeling and FVS

- FVS is a growth and yield simulation system from the category of individual-tree, distance-independent models.
- FVS system is composed of 4 main components that work together to simulate growth and the effect of treatments: a mortality sub-model, a large-tree growth sub-model, a small-tree growth sub-model and an establishment sub-model. The population unit for FVS is a forest stand.
- Pre-processors are applications that prepare data in different formats to be used as input for FVS. The post-processors are programs that manipulate further the FVS output for reporting and analysis.
- Suppose is the graphical interface for FVS.
- The files required by Suppose are: FVS Tree Data File (extension .fvs), Suppose Stand List File (.slf) and Suppose Locations File (.loc).

USDA Forest Service, FMSC. (Ed.) (2001a, October 12 – last update) FVS model. [Online]. Available: <http://www.fs.fed.us/fmfc/fvs/description/model.php> [2003, March 10]

Crookston, Nicholas L. 1997. Suppose: An Interface to the Forest Vegetation Simulator. In: Teck, Richard; Moer, Melinda; Adams, Judy, comps. 1997. Proceedings: Forest Vegetation Simulator conference. 1997 February 3-7; Fort Collins, Co. Gen. Tech. Rep. INT-GTR-373. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station: 7-14.

Forest Inventory and Analysis (FIA) database

- FIA is a program of USDA Forest Service and is providing the most comprehensive forest ecosystem inventory in the US.
- FIA data available for Indiana comes from inventories in 1986, 1998, 1999 and 2000.
- FIADB structure. The COND table provides information on the discrete combination of landscape attributes that define the condition. A row in the TREE table is used to describe each tree over 1 inch in diameter found on a subplot.
- Plot location: GIS-FIA model uses the latitude-longitude coordinates to locate the FIA plot points for 11 states in the North Central region

Miles, Patrick D. et. al. (2001, June 1 – last update) FIA Database Retrieval System. The Forest Inventory and Analysis Database: Database Description and Users Manual Version 1.0. Revision 8. [Online]. Available: http://www.ncrs.fs.fed.us/4801/FIADB/fiadb_documentation/FIADB_DOCUMENTATION.htm [2003, February 15]

Pugh, Scott A., Reed, David D., and Pregitzer, Kurt S.. (2000). GIS-FIA Model User's Guide, [CD-ROM]. Michigan Technological University. Houghton, MI.

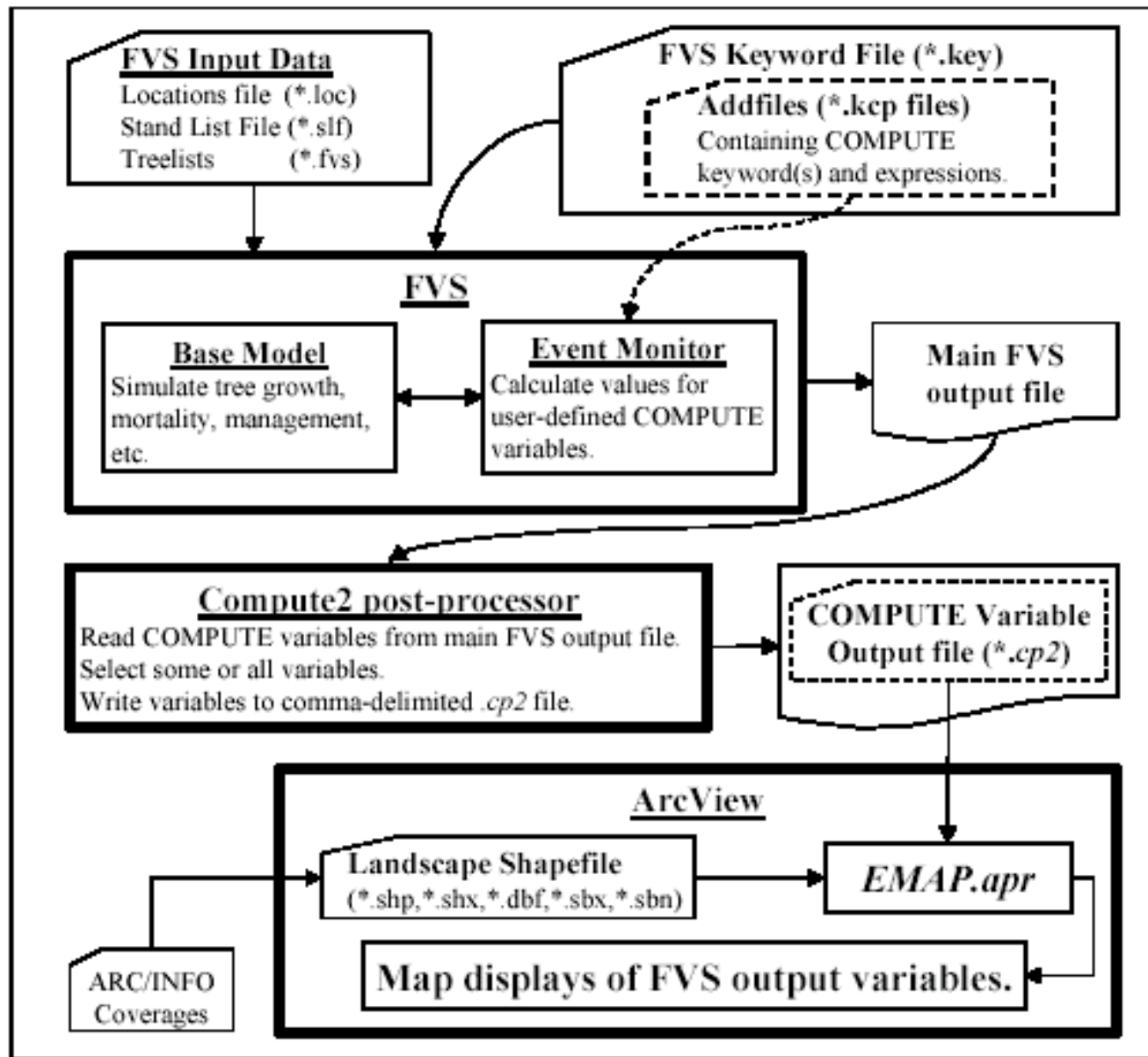
Existing GIS extension for FVS: FVS-EMAP

FVS-EMAP is a simple tool that allows FVS variables to be imported, analyzed, and displayed in ArcView GIS.

Functions:

- load and link a CP2 output file to the stand polygon shapefile
- animate the active View by displaying each Theme (one for each cycle of the simulation) one at a time
- create a record file for PPE keyword AREALOCS by extracting polygon areas, and coordinates of polygon centers, and rewrite the extracted information into a file formatted for FVS

McMahan, Andrew J.; Anthony Courter; Eric L. Smith. 2002. User's Guide for FVS-EMAP: A simple tool for displaying FVS output in ArcView.. FHTET 02-01. Fort Collins, CO: USDA Forest Service, State & Private Forestry, Forest Health Protection, Forest Health Technology Enterprise Team. 30 p.



Flowchart diagramming the flow of information from FVS and the Event Monitor into the FVS-EMAP ArcView project EMAP.apr

2. Methods

- ArcGIS, ArcObjects and VBA advantages
- The structure of ArcFVS application
- ArcFVS flow chart

ArcGIS, ArcObjects and VBA advantages

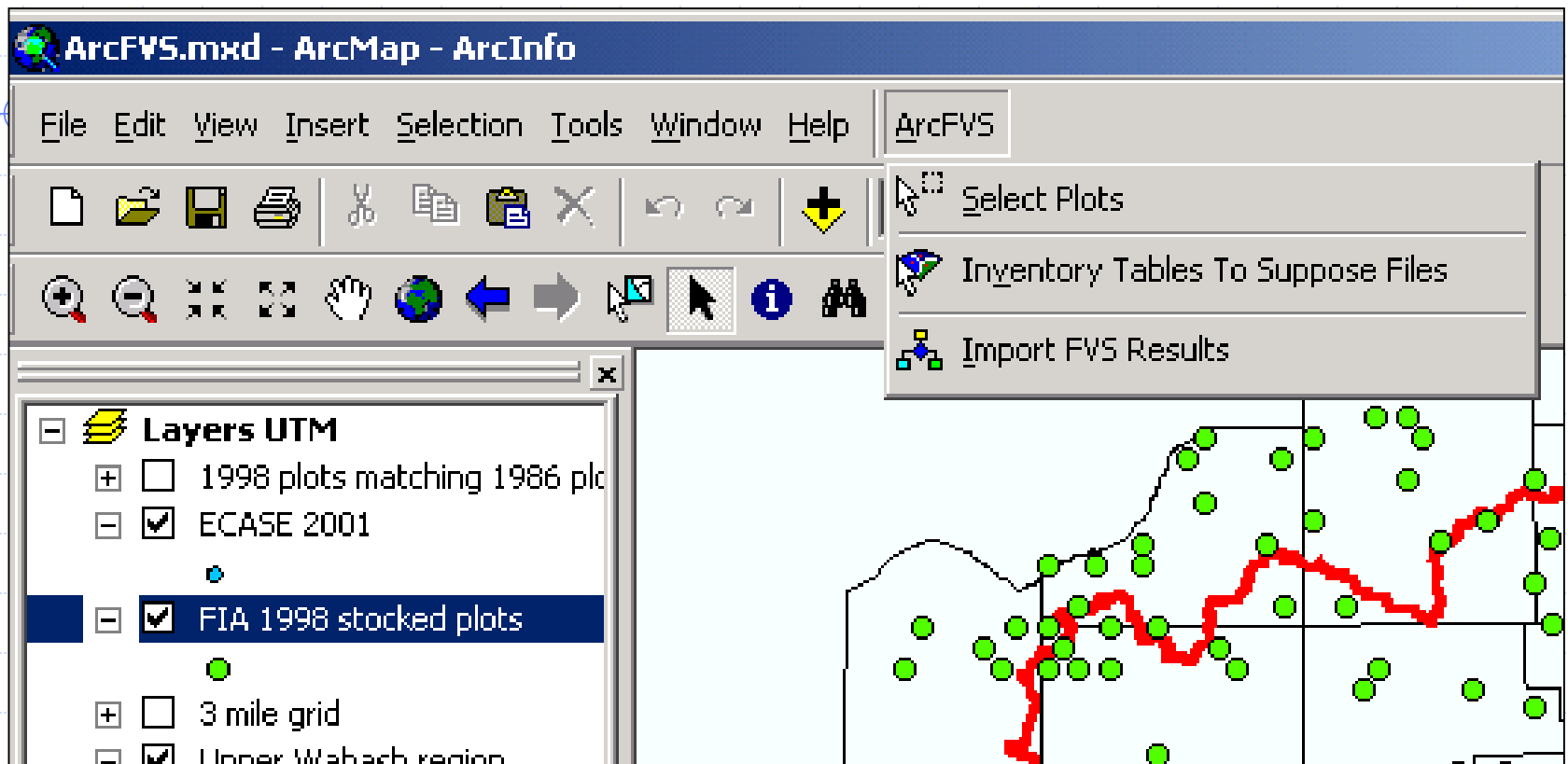
- ArcGIS is a scalable family of GIS software built on industry standards.
- Customization in ArcGIS is possible using VBA and ArcObjects.
- ArcObjects are software components based on Component Object Model (COM) protocol that have GIS functionality and programmable interfaces.
- They can be used by the built-in VBA scripting language or independent of ArcGIS in a programming language such as Visual Basic (VB), Visual C++ or Delphi.
- Advantages of ArcGIS and ArcObjects programming over ArcView 3.x and AVENUE: standard Windows user interface, standard programming interface, standard data format and terminology.
- Some disadvantages: the large existing collection of custom applications designed for ArcView 3.x and the change required from the GIS users and programmers of adapting to the new software and programming environment.

ESRI. (Ed.). (2003b, October 13 - last update). ArcGIS overview, [Online]. Available: <http://www.esri.com/software/arcgis/overview.html> [2003, October 20].

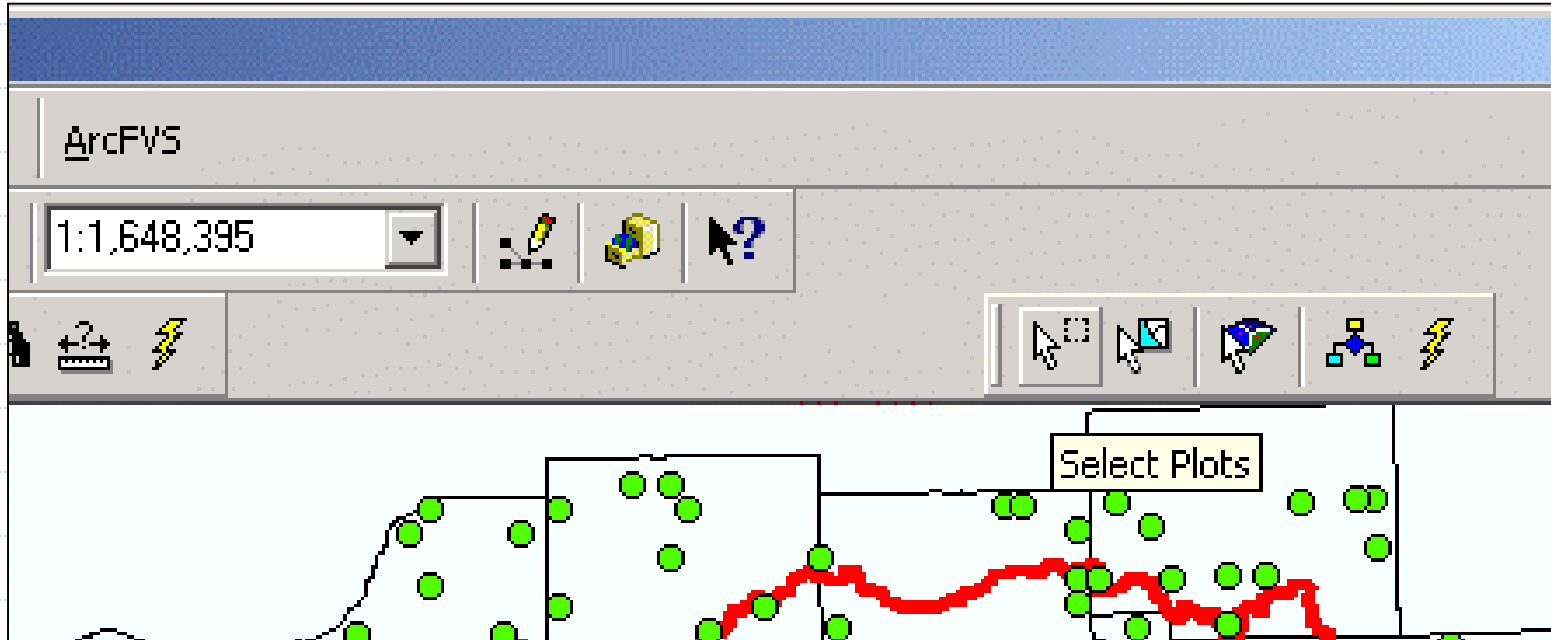
ESRI. (Ed.). (2003d, October 13 - last update). ArcObjects. [Online]. Available: <http://www.esri.com/software/devsolutions/arcobjects/index.html> [2003, October 20].

Structure of ArcFVS

- One custom menu and one custom toolbar in an Map Document.
- Three functions: Select Plots, Convert Inventory Tables to Suppose Files, and Import FVS Outputs.
- The toolbar contains two additional tools from the standard ArcMap tools: Select Features and Hyperlink.

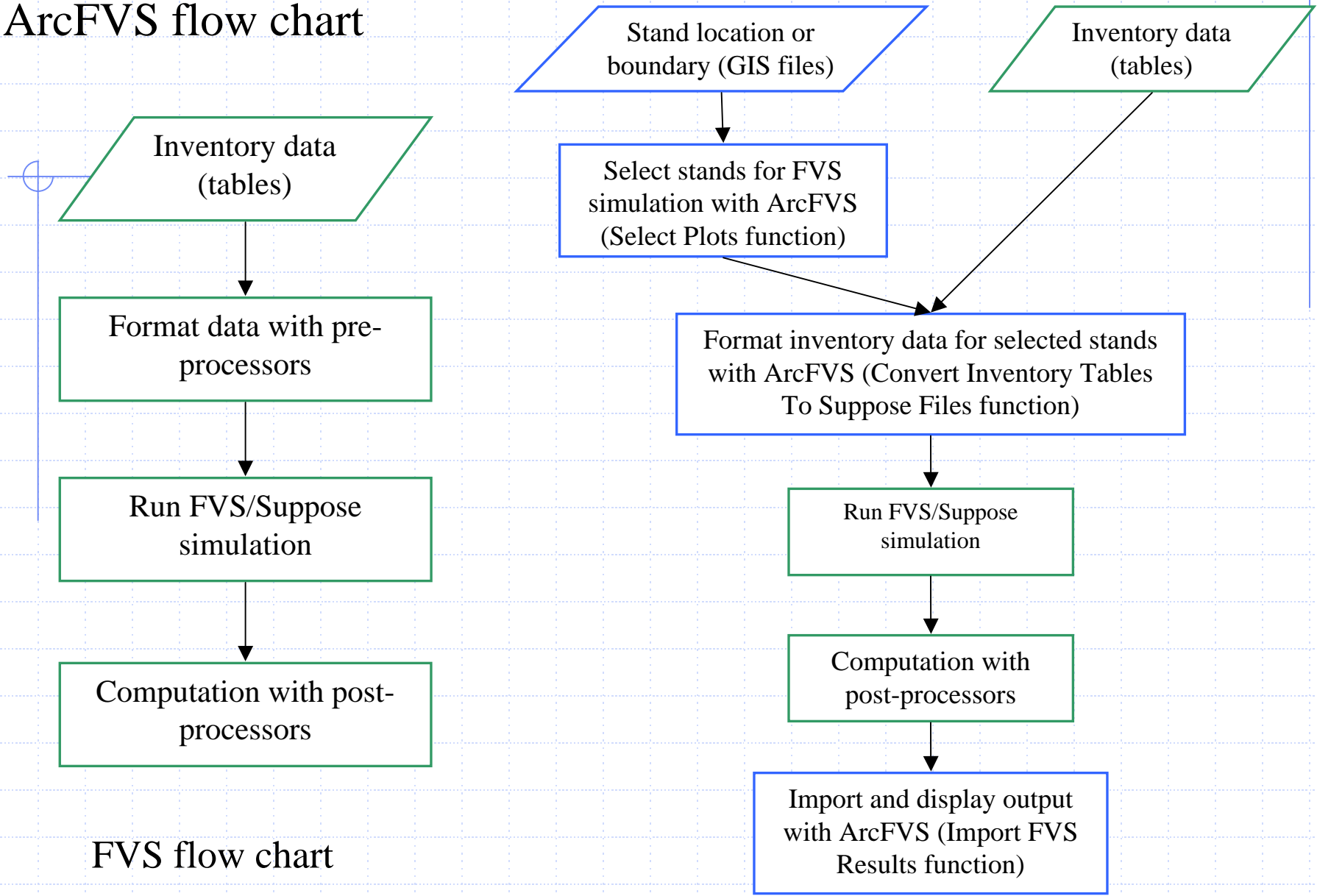


ArcFVS menu and custom commands



ArcFVS toolbar with three custom tools and two standard tools

ArcFVS flow chart



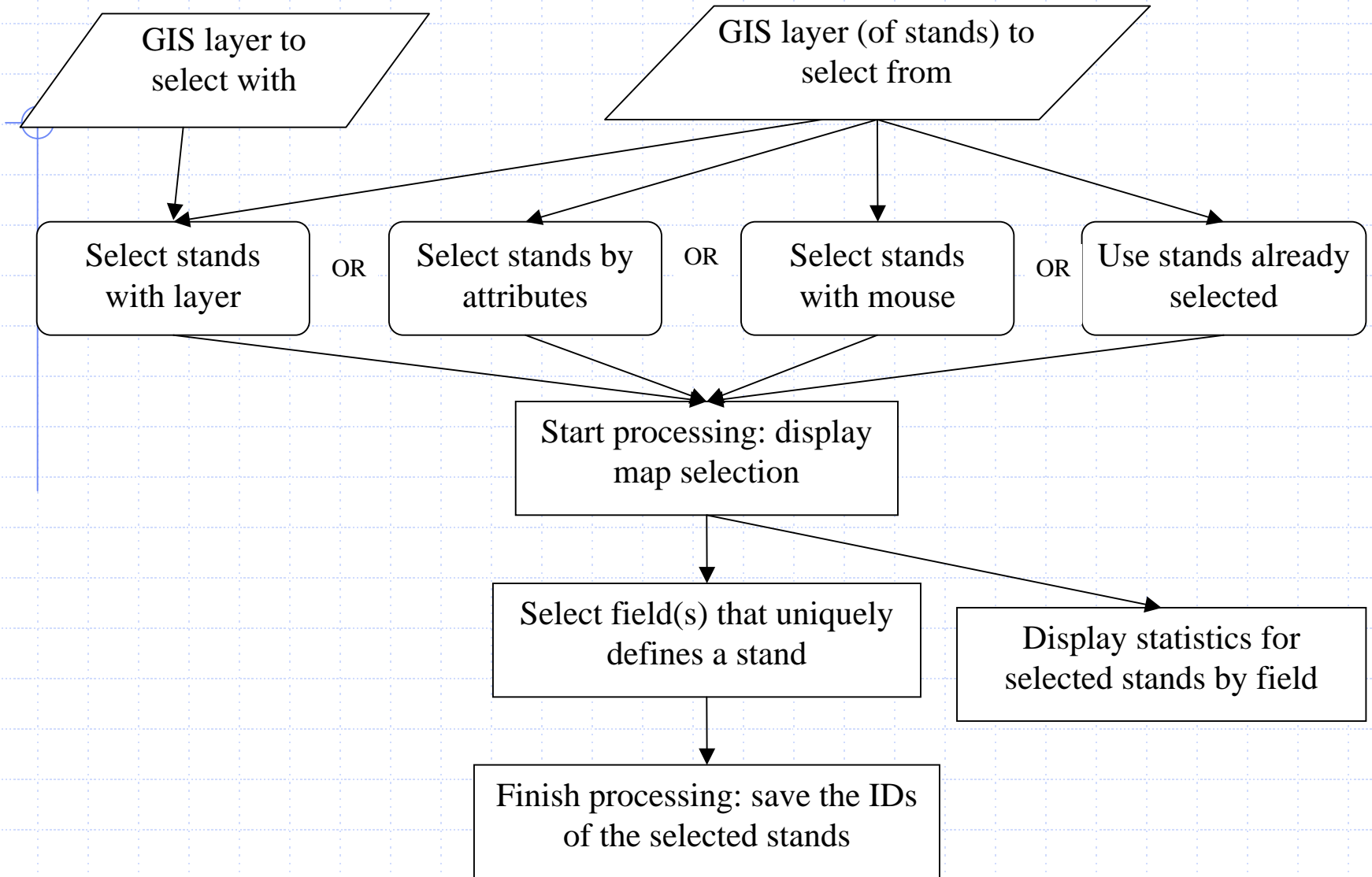
FVS flow chart

ArcFVS flow chart (its specific functions are in blue text boxes)

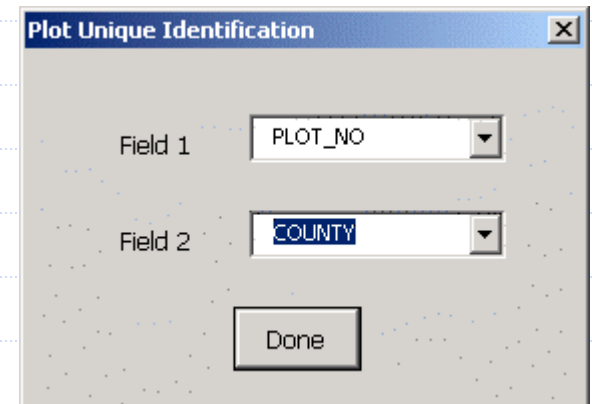
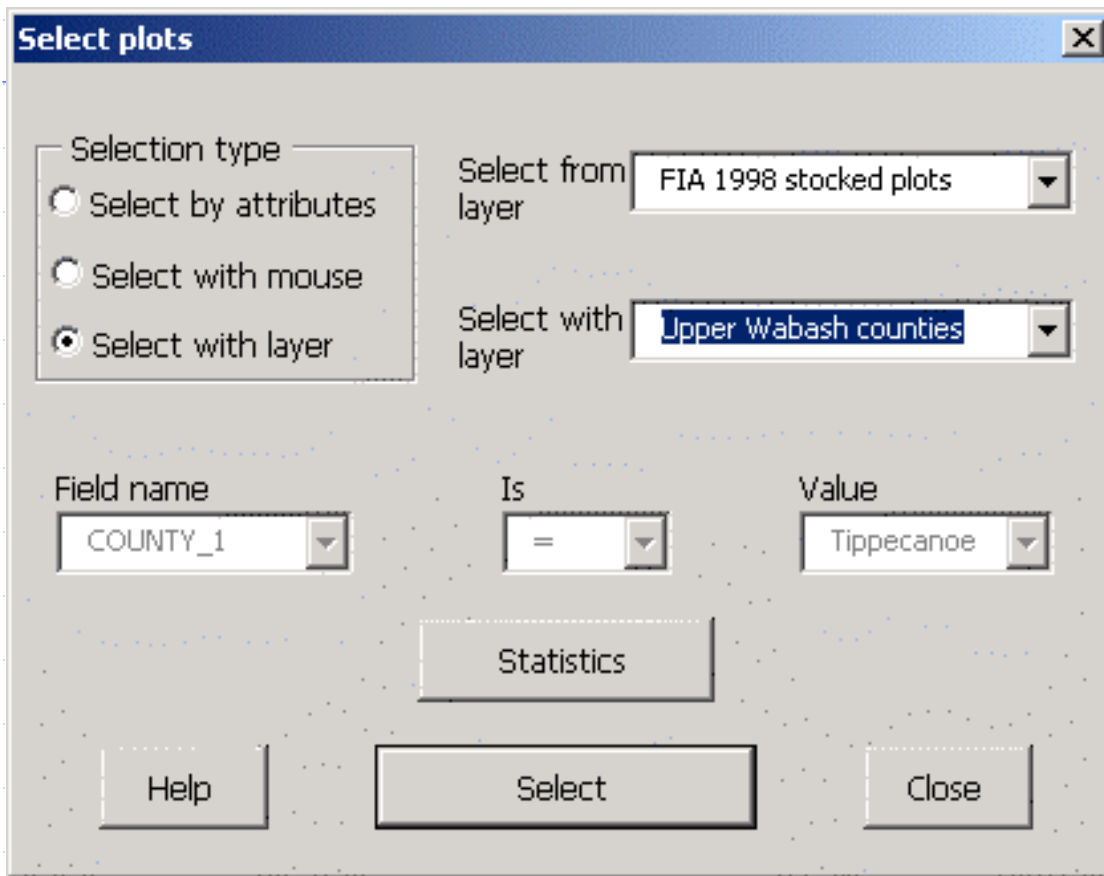
3. System development

- Select Plots function
- Convert Inventory Tables To Suppose Files function
- Import FVS Outputs function
- Programming details

Select Plots

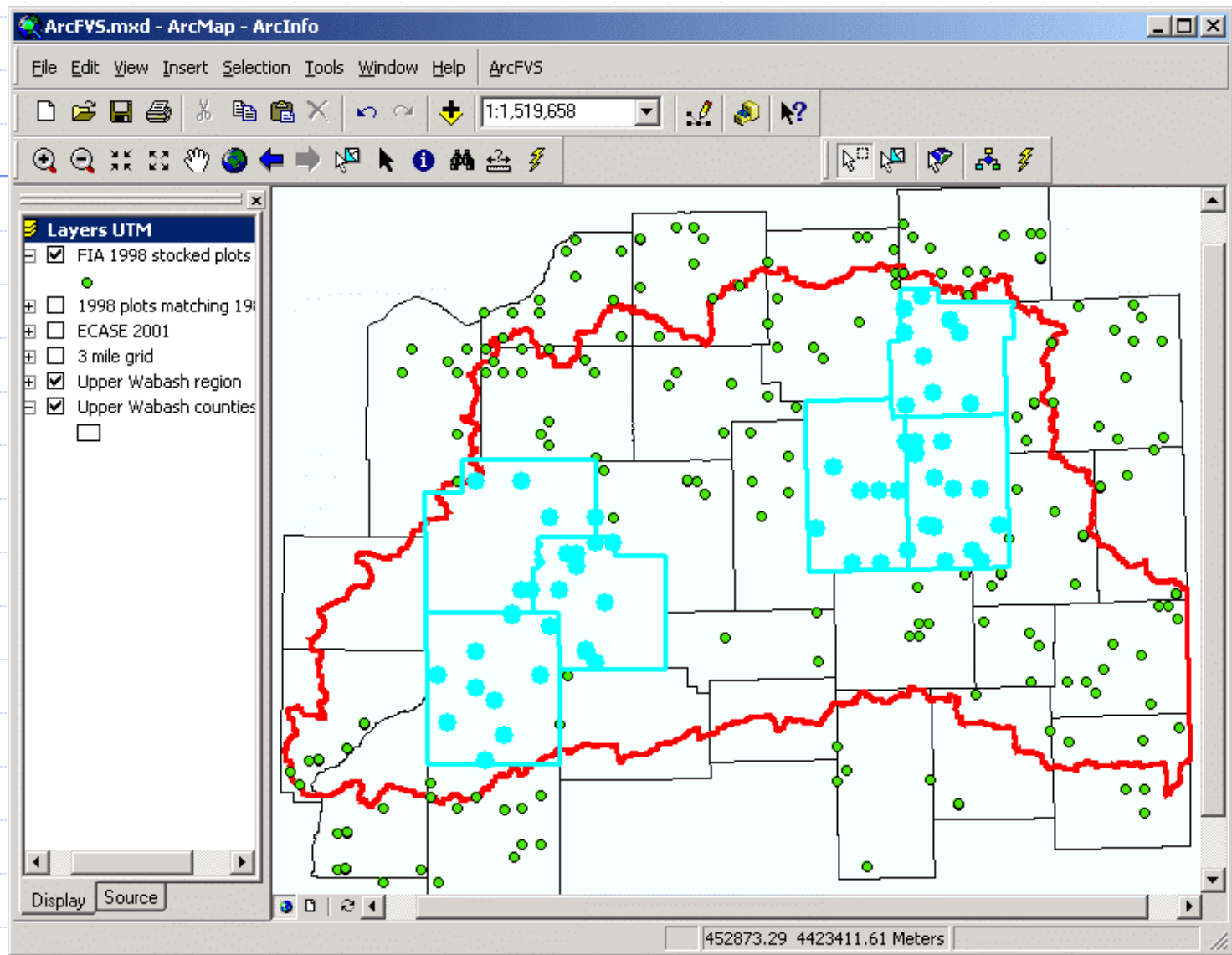


Flow chart for Select Plots function



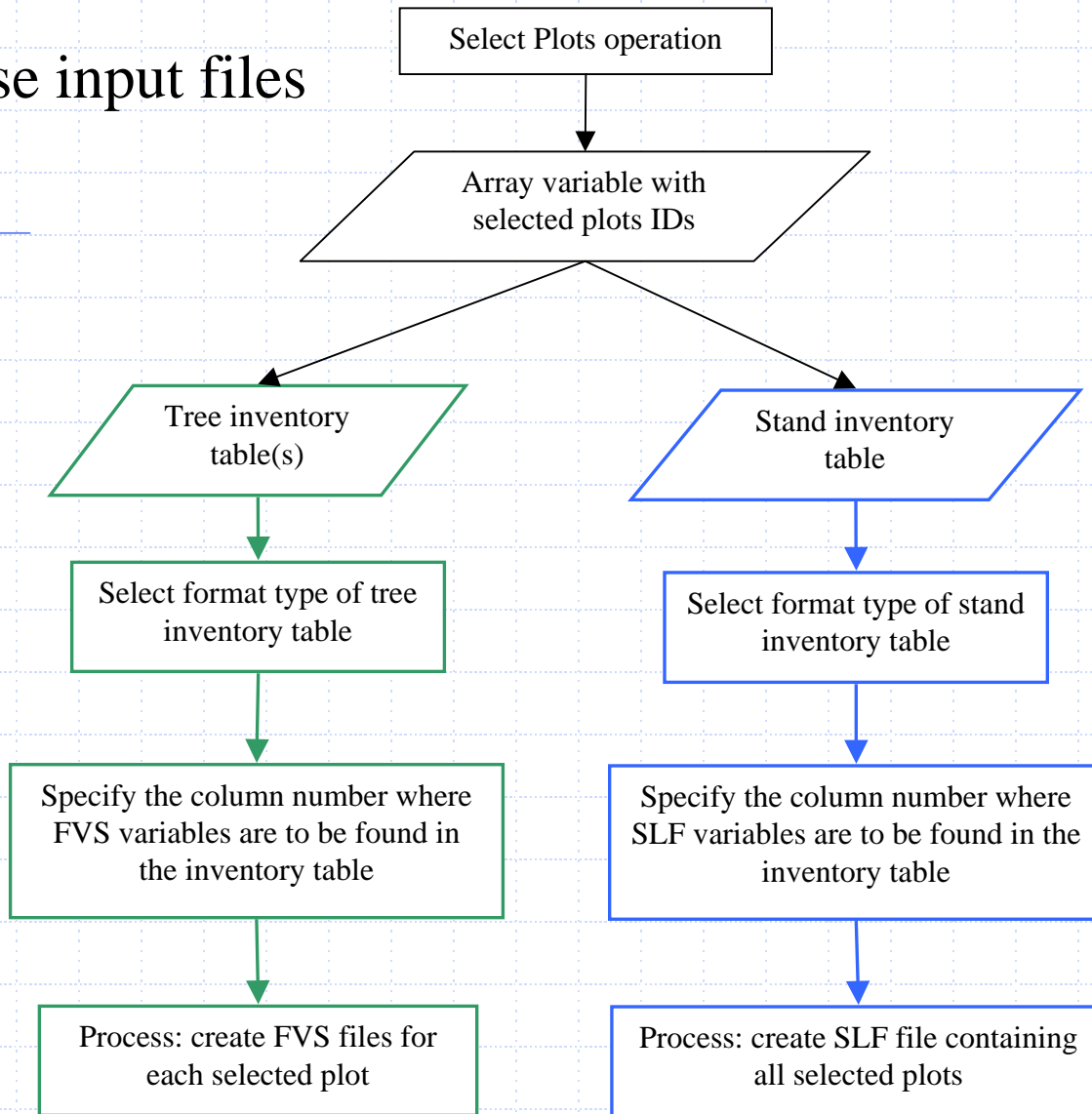
Specify the fields that uniquely identify a plot

Select Plots using the Select With Layer option



Selection of plots using the selected counties

Create Suppose input files



Flow chart of the Convert Inventory Tables To Suppose Files operation

Inventory tree tables to FVS files [X]

Type of file
 csv files
 xls file

Input folder: [Browse]

Output folder: [Browse]

One file for all plots The file has a header

Tree Attributes

	Field No.		Field No.
Plot ID	<input type="text" value="9"/>	Crown ratio	<input type="text" value="27"/>
Tree ID	<input type="text" value="10"/>	Damage code 1	<input type="text"/>
Tree count	<input type="text" value="41"/>	Severity code 1	<input type="text"/>
Tree status code	<input type="text" value="16"/>	Damage code 2	<input type="text"/>
Species code *	<input type="text" value="19"/>	Severity code 2	<input type="text"/>
DBH *	<input type="text" value="21"/>	Damage code 3	<input type="text"/>
Diameter increment	<input type="text"/>	Severity code 3	<input type="text"/>
Total height	<input type="text"/>	True value class	<input type="text"/>
Height to break/topkill	<input type="text"/>	Prescription code	<input type="text"/>
Height increment	<input type="text"/>		

Examples

*** Required**

[Help] [Process] [Next Step >>]

“Inventory tree tables to FVS tree file” form

Inventory stand file to SLF file [X]

File type
 csv file
 xls file

Input file:

Output file:

The input file has a header

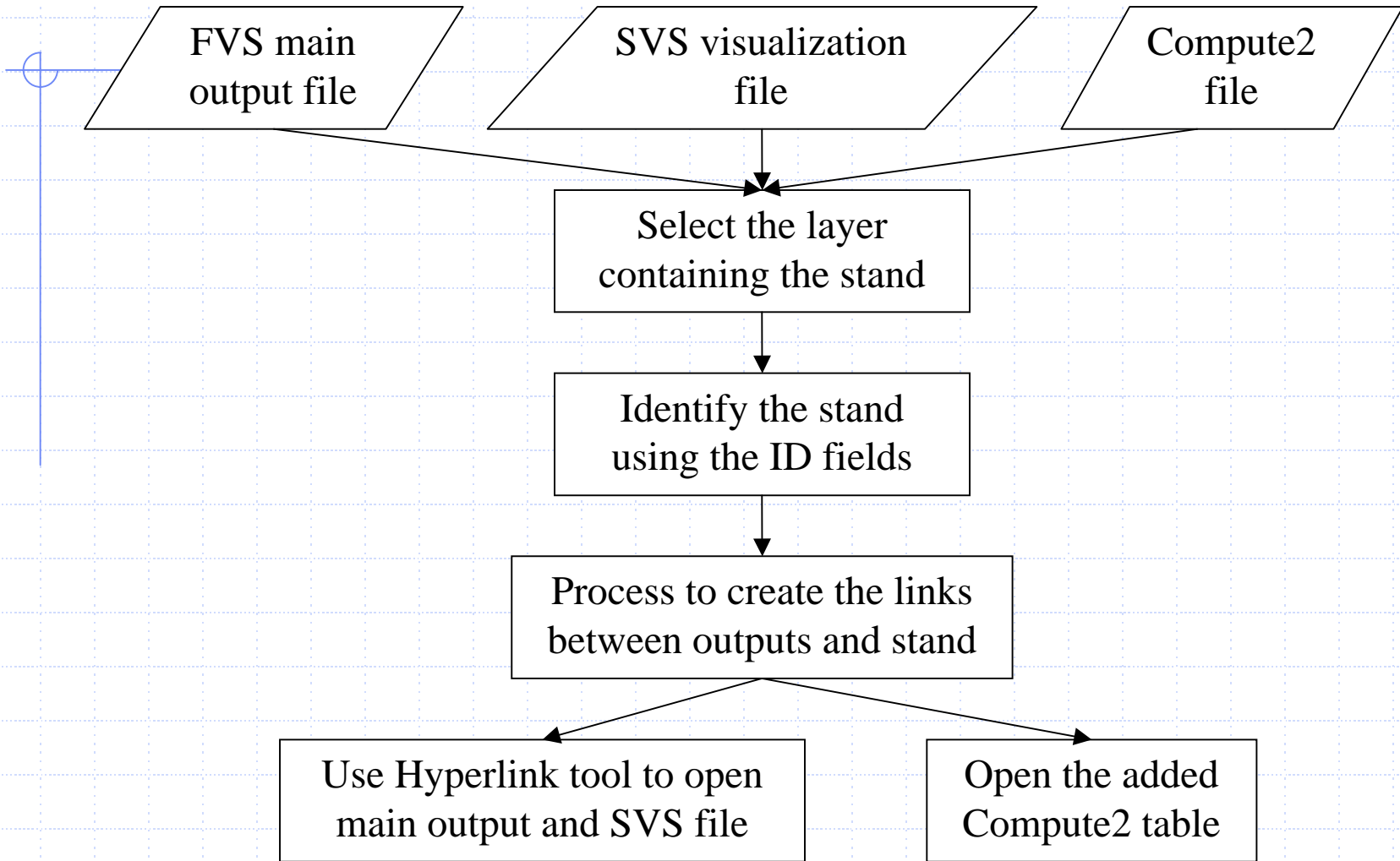
Stand attributes

	Field No. or Const. Value	Const.		Field No. or Const. Value	Const.		Field No. or Const. Value	Const.
Inventory year	<input type="text" value="1998"/>	<input checked="" type="checkbox"/>	Inverse of fixed plot size (acres)	<input type="text" value="75"/>	<input checked="" type="checkbox"/>	Mortality period (years)	<input type="text"/>	
Latitude	<input type="text" value="40"/>	<input checked="" type="checkbox"/>	Breakpoint DBH	<input type="text" value="5"/>	<input checked="" type="checkbox"/>	Maximum BA (sq ft/ac)	<input type="text"/>	
Longitude	<input type="text"/>	<input type="checkbox"/>	Number of plots	<input type="text"/>		Maximum SDI	<input type="text"/>	
Location (region/forest)	<input type="text" value="911"/>	<input checked="" type="checkbox"/>	Non-stockable plots	<input type="text"/>		Site species	<input type="text"/>	
Habitat type code	<input type="text"/>		Stand weight or size	<input type="text"/>		Site index	<input type="text" value="24"/>	
Stand origin year	<input type="text"/>		Stockable %	<input type="text"/>		Model type	<input type="text"/>	
Aspect (degrees)	<input type="text" value="30"/>		Diameter growth code	<input type="text"/>		Forest type	<input type="text" value="17"/>	
Slope (%)	<input type="text" value="29"/>		Diameter growth period (years)	<input type="text"/>		Physiographic region	<input type="text"/>	
Elevation (100s feet)	<input type="text"/>		Height growth code	<input type="text"/>		County	<input type="text" value="1"/>	
Basal area factor	<input type="text" value="6"/>	<input checked="" type="checkbox"/>	Height growth period (years)	<input type="text"/>		Plot ID	<input type="text" value="8"/>	
						Age	<input type="text" value="20"/>	

Examples

“Inventory stand table to Suppose stand list file” form

Import FVS outputs



Flow chart of the Import FVS Output function

Import FVS outputs [X]

Link Layer: FIA 1998 stocked plots

1st ID Field: COUNTY is 15

2nd ID Field: PLOT_NO is 22

Link Stand: COUNTY is 15 PLOT_NO is 22

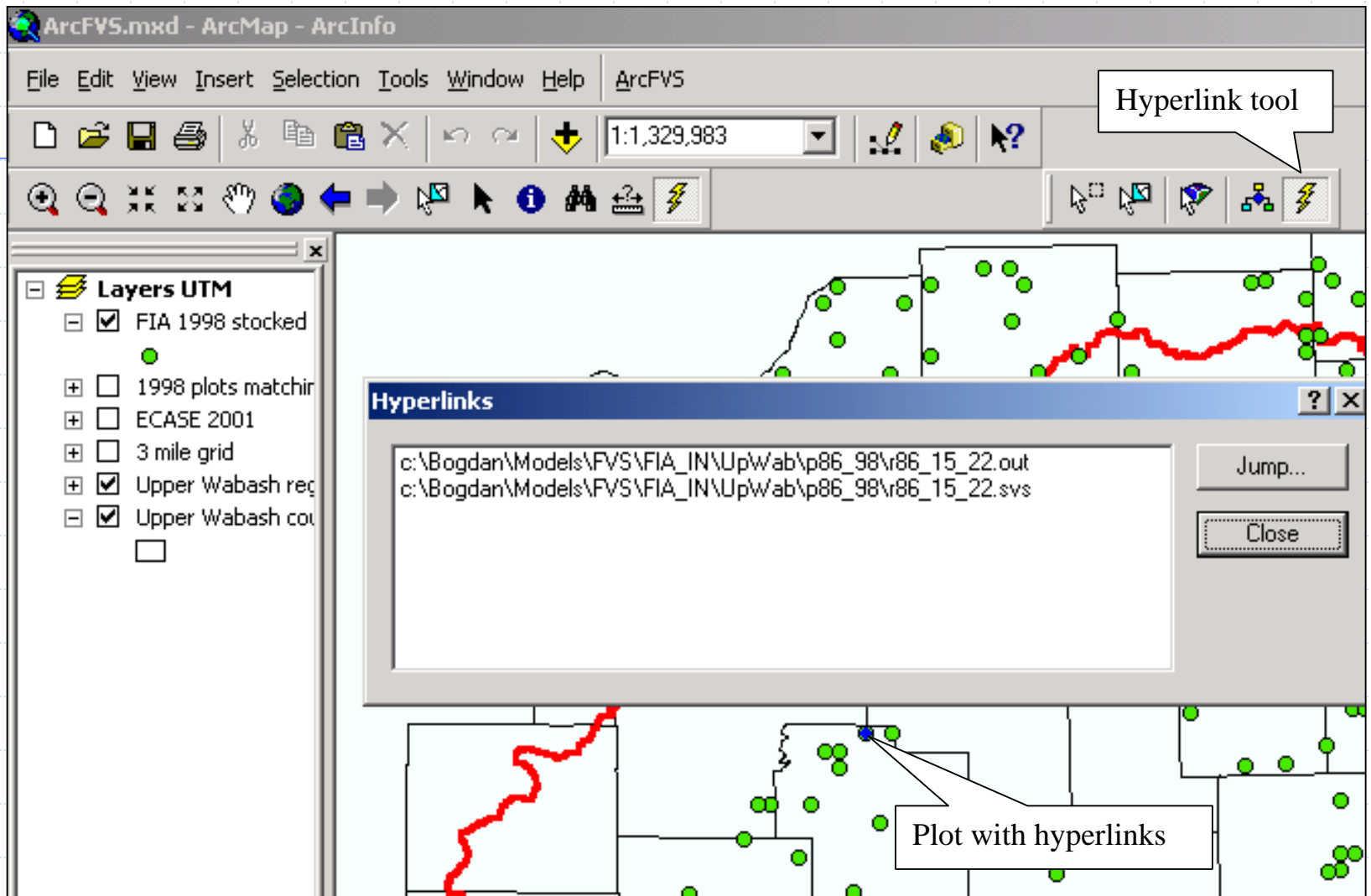
FVS Output File: c:\Bogdan\Models\FVS\FIA_IN\UpWab\p86_98\r86_15_22.out [Browse]

Compute2 File: c:\Bogdan\Models\FVS\FIA_IN\UpWab\p86_98\r86_15_22.cp2 [Browse]

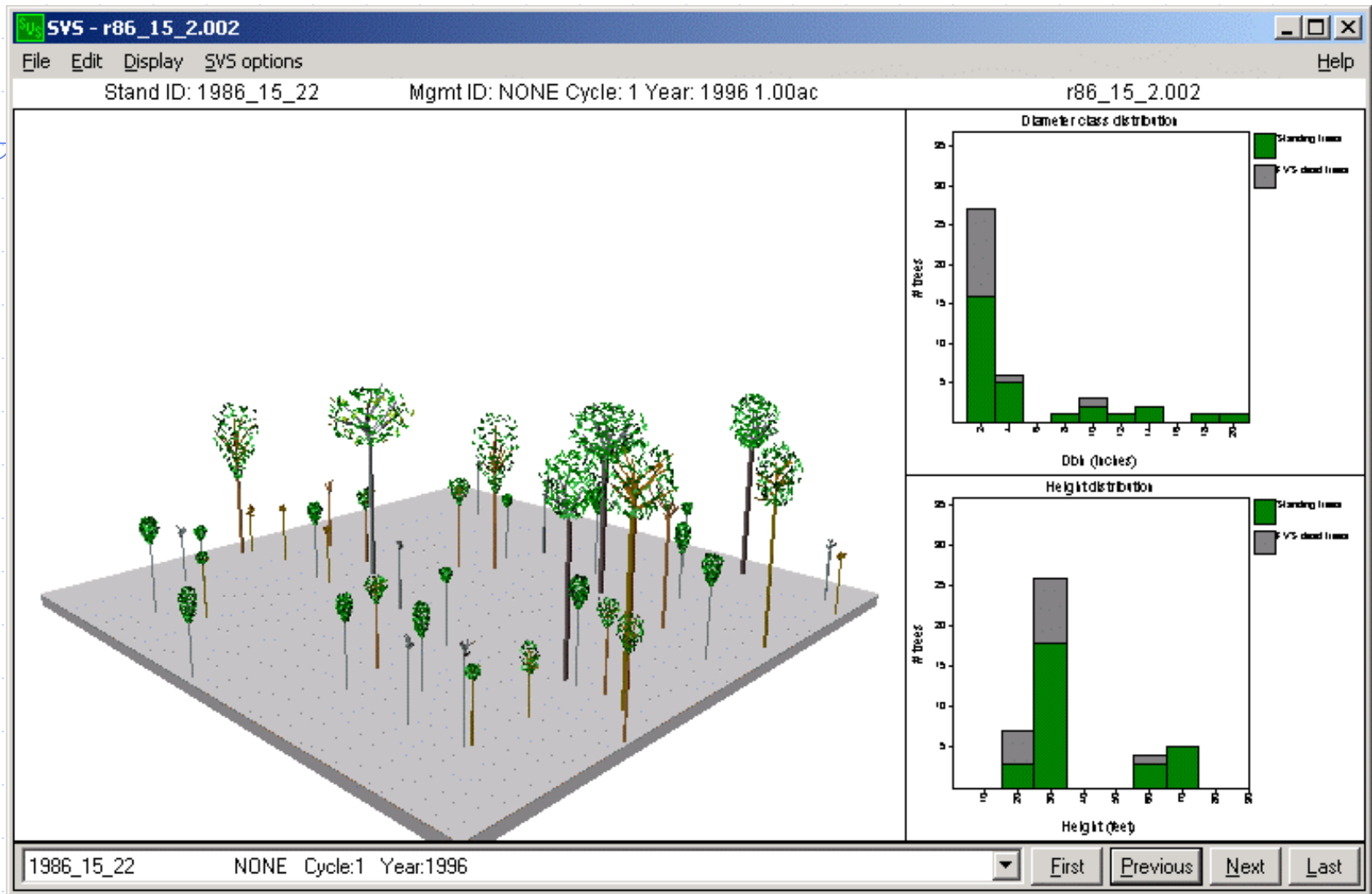
Visualization File: c:\Bogdan\Models\FVS\FIA_IN\UpWab\p86_98\r86_15_22.svs [Browse]

[Help] [Process] [Close]

Import FVS Outputs window

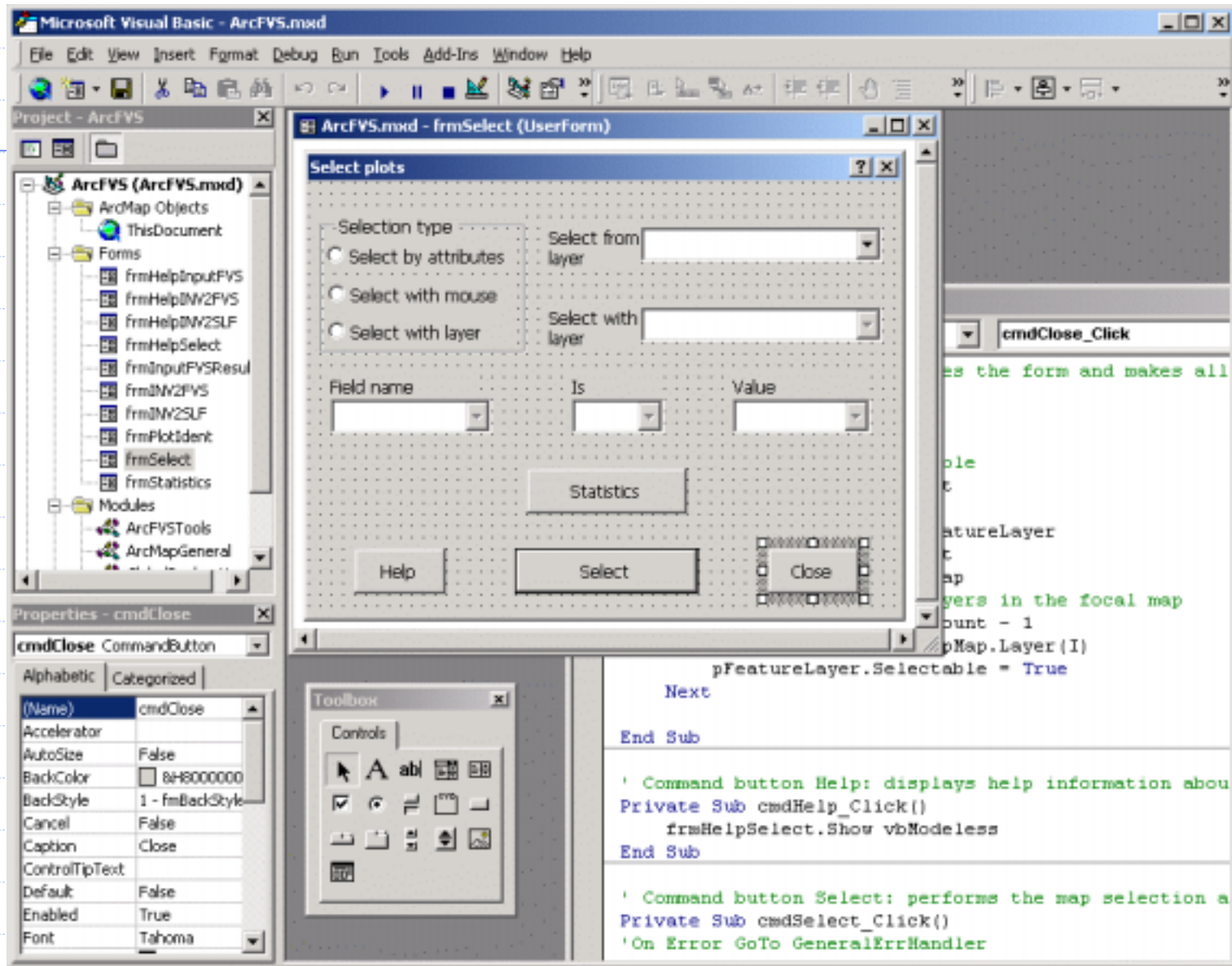


Hyperlinks to output file and SVS file created for one stand in the selected layer



SVS window for one cycle opened by the dynamic hyperlink

Programming details



VB editor where the design and code writing for each custom form takes place

Conclusions

- Achievement of the specific objectives
- Advanced Features of ArcFVS
- The Potentials of ArcFVS
- Possible Applications of ArcFVS

Achievement of the specific objectives

ArcFVS is designed as a customization of the ArcGIS software that integrates GIS analysis with the FVS modeling capabilities.

- ArcFVS offers an easy way for selecting forest stands with spatial and attribute criteria, for translating the inventory data of the selected stands to Suppose ready files and for importing the FVS outputs to be displayed and analyzed with GIS specific tools.
- ArcFVS is built on the widely-used standard programming platform of VBA (visual, procedural, object-oriented) and uses the versatile ESRI software components ArcObjects. ArcGIS technology is strongly promoted by ESRI and is gradually replacing ArcView GIS.
- The selection of the stands can be done in ArcFVS in different ways: by attribute, using selected features from another layer, and with the mouse.
- The conversion from the inventory tables to Suppose ready files can handle CSV and XLS files (Excel type is a new addition). In the case of formatting for FVS tree files, multiple input files can be processed at the same time, and multiple plots data formatting for SLF file is also automated.

Advanced Features of ArcFVS

- Improve data validation and error handling by creating standard procedures and operating rules to cover all the data input and processing steps.
- Create a more extensive input capability for translation to Suppose files, by allowing more file types (text files with values separated in columns, Access database tables, etc) and data structures to be processed.
- Allow more FVS outputs to be imported, displayed and analyzed in the GIS environment and improve the GIS integration of those outputs
- Save the conversion settings so they can be loaded for other data sets
- Save the plot selection so it can be used in another ArcMap session

The Potentials of ArcFVS

- Current format – custom ArcGIS Map document
- Other options: extension to ArcGIS (DLL file) or independent application built with Visual Basic and ArcObjects
- Future environment: web based interface, which would allow GIS analysis and FVS simulation run from an Internet browser

Possible Applications of ArcFVS

1. Research applications
 - To examine forest dynamics in the Upper Wabash Basin
 - To develop multidisciplinary landscape models
2. Professional foresters and forest managers applications
 - To run a web-based FVS using the research data collected by FNR
 - To run FVS with newly collected data
3. Education applications
 - To increase the FVS learning speed by easing the data formatting process
 - To illustrate the relation between the simulation process of FVS and the stands geospatial associations.

Acknowledgements

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