

Chapter 4 Implementation of GIT in State Forestry Organizations

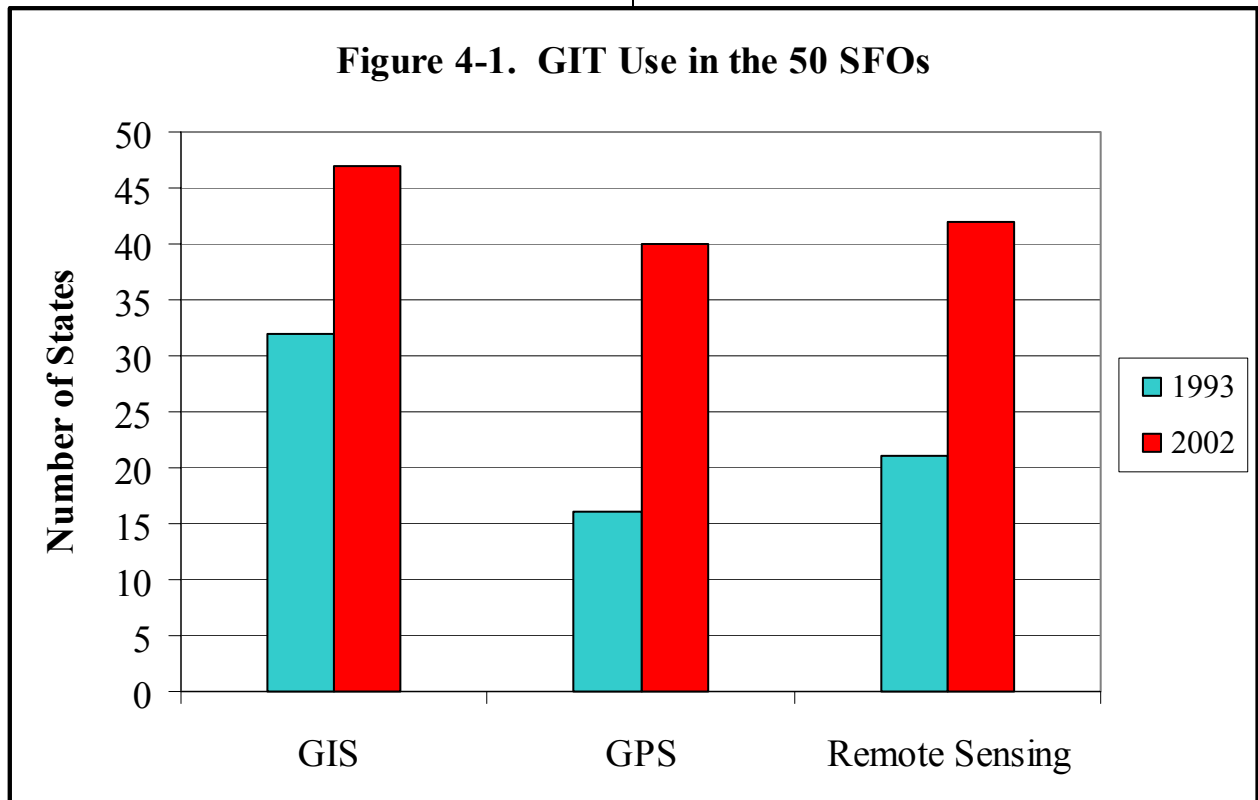
Some of the earliest and most extensive use of GIT in state governments is located in SFOs. This chapter provides an overview about GIT presence in the nation's 50 SFOs and summary information about GIT applications based on information provided by the state foresters and their staff. Detailed information about the most frequent applications and examples from individual SFOs for these applications is provided in Chapter 5. The content of both chapters is derived from information provided by each of the SFOs, as included in Section 2 of the "State Profiles" in Appendix C.

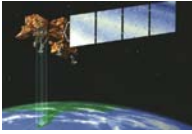
4.1 Growth of GIT Use in SFOs

The profiles indicate that all 50 SFOs use GIT, and most use all three types of the technology (geographic information systems [GIS], remote sensing [RS], and the Global Positioning System [GPS]) to some extent. However, they also reveal

a great disparity in this usage, both today and over time. While the focus of the profiles was to characterize conditions now, and they are generally current as of early 2002, the profiles reveal that some SFOs have been extensive users of GIT for a long time. For example, Washington's Department of Natural Resources initiated aerial mapping programs in the 1950s, and has been using automated mapping and satellite data since the mid 1970s. Other SFOs have only recently begun to use the technology.

As shown in **Figure 4-1**, summary information from the profiles was compared to a related survey with NASF and SUNY-ESF about SFOs in 1993 (Warnecke and Herrington 1994). All 50 SFOs also responded to that query, with the written survey instrument asking direct questions regarding GIS, GPS and RS use. This comparison reveals that GIT use in SFOs has increased significantly over the past eight years.



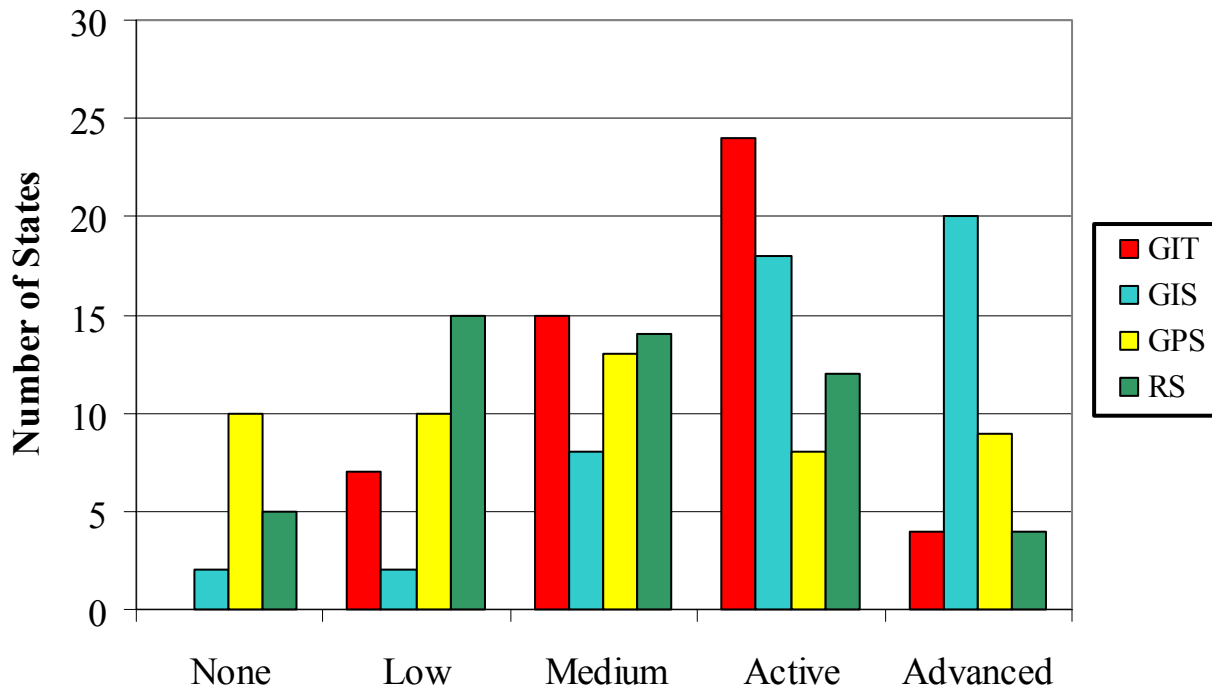


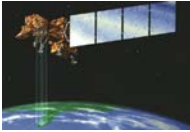
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In comparing the three technologies, the greatest gains were observed in GPS use. Between 1993 to 2002, the number of SFOs reporting usage of GPS grew from 16 to 40, representing an increase of 150%. The actual number of SFOs using GPS today is likely much larger, and use of the technology may exist in all SFOs. This is because the leading focus of the profiles was to ascertain remote sensing, and to a lesser extent, GIS usage. Profile participants were not specifically encouraged to provide information about GPS, but 40 SFOs reported its usage. The results clearly reflect dramatic improvements, cost reductions, and resulting proliferation of GPS technology. In fact, some SFOs reported widespread deployment of GPS receivers throughout their organizations, such as in Florida and Maine.

Comparison of the results also reveals a significant increase in the use of remote sensing. The number of SFOs using RS doubled from 21 to 42, with another three SFOs (in Georgia, Illinois and Louisiana) indicating that another agency in their state uses it for forestry related applications. Advances in the availability and accuracy of remotely sensed data, as described in Chapter 2, are likely reflected by this growth in adoption since 1993. At the same time, the results may reflect the increasing incidence and maturity of statewide GIT coordination efforts, as described in Chapter 1. Coordination efforts can increase exposure and cooperative efforts to share the costs and benefits of imagery acquisition with others.

Figure 4-2. Overall GIT Presence





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While the increase in GIS use was the least of the three technologies when comparing the results of the two queries, this is largely the case because almost two thirds of the SFOs indicated GIS use in 1993. The profiles reveal that 47 SFOs now use GIS, an increase of nearly 44%. An additional state, Rhode Island, indicated that another state agency uses GIS for forestry related applications. While participants were not asked to indicate specific software products, the majority who did so indicated that they use software developed by Environmental Science Research Institute (ESRI).

4.2 Current GIT Presence in SFOs

While comparisons between the 1993 survey and current profiles are useful, more in depth information and analysis is available from the profiles. For example, based on a systematic, detailed evaluation of the contents of each profile, the SFOs were determined to be low, medium, active or advanced GIT users. As shown in **Figure 4-2**, almost half of the SFOs (24) were found to be active GIT users. An additional four states were found to be advanced users, reflecting sophisticated use of all three technologies (GIS, GPS and RS). While only four states were indicated as advanced users of all GIT, an additional 16 states were determined to use GIS at an advanced level, while nine states were identified as advanced GPS users.

As indicated above, when comparing the three technologies, GIS is the most pervasively used, followed by GPS technology. As shown in **Figure 4-3**, mean, median, and mode figures for overall presence are substantially higher for GIS than for the other two technologies. **Figure 4-4** also reveals greater GIS adoption than for the other two technologies, as shown by a greater frequency of active and advanced GIS users (indicated as "high" in this figure). Of the three technologies, GIS has clearly penetrated the SFOs to the greatest extent with 38 (or 76%) of

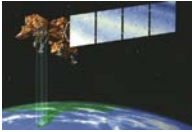
them being active or advanced users. In contrast, the number of SFOs with active or advanced GPS use is 17 (or 34%) and for remote sensing it is 16 (or 32%).

Figure 4-3. Mean, Median and Mode Values for GIT/GIS/GPS/RS

	GIT	GIS	GPS	RS
Mean	2.5	3.04	1.92	1.9
Median	3	3	2	2
Mode	3	4	2	1

When considered individually, fewer numbers of SFOs have achieved an advanced level of RS usage. However, a query of statewide GIT coordinators in the mid 1990s indicated that forestry is one of the most frequent applications of RS use among all state governments (Warnecke 1997).

Correlation analyses show a significant relationship between the levels of GIT and each of the technologies (Pearson correlation coefficient significant at 0.01 level, except for GPS – at 0.05 level). GIS use appears to be highly correlated with RS use. In addition, the categorization into high and low levels of GIT presence in SFOs seems to be primarily driven by the use of GIS and RS technology. For example, all SFOs (except one) that are identified as a high GIT user are also high users of GIS. All SFOs (except one) that are identified as a low level GIS user, are also limited in their overall GIT usage. Furthermore, all agencies high in use of RS are also designated as high in their overall GIT presence.



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Figure 4-4. Frequency and Percent of Low and High SFO Users of GIT/GIS/GPS/RS*

GIT	Frequency	Percent
Low	22	44%
High	28	56%
GIS		
None	2	4%
Low	10	20%
High	38	76%
GPS		
None	10	20%
Low	23	46%
High	17	34%
RS		
None	5	10%
Low	29	58%
High	16	32%
Total	50	100%

*Low = Low or Medium
High = Active or Advanced

An evaluation also was conducted to determine if regional differences (according to the four standard U.S. Census Bureau regions described in Chapter 1) are statistically significant in terms of GIT, GIS, GPS or RS presence in SFOs. The incidence of higher or lower levels of usage among the regions was not found to be statistically significant. However, **Figure 4-5** reveals some regional disparity based on a simple tabulation of the findings for each region. All but one SFO in each region indicated they use GIS, except in the West where all SFOs use GIS. GPS and remote sensing use is more variable by region. The least use of GPS is in the Northeast with 6 SFOs, representing 66.7%, and the least use of remote sensing is in the South with 12 SFOs or 75%.

To examine if the level of GIT usage is associated with external factors, GIT presence information derived from the profiles was correlated with the following variables derived from the report entitled *State Forestry Statistics - Fiscal Year 1998 Report*, which included responses from all states except Alaska (Dupree 1998) and data available about each state from the U.S. Census Bureau:

Forested lands

- acres of forested land
- acres of state-owned forested land
- percentage of state land that is forested

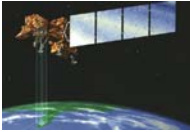
SFO expenditures and revenues

- expenditures - total and per acre of state-owned forest land
- management-related expenditures - total and per acre of state-owned forest land
- revenue - total and per acre of state-owned forest land

State populations

- in year 2000 (total and rank)
- density in year 2000
- change from 1995 to 1999.

Four variables were correlated with GIT level of use in a statistically significant manner: acres of forest land (Pearson correlation coefficient of 0.35 significant at 0.014 level), acres of state-owned forests (Pearson correlation coefficient of 0.32 significant at 0.26 level), management-related expenditures (Pearson correlation coefficient of 0.29 significant at 0.053 level), and total SFO revenue (federal/state/other support and revenue) (Person correlation coefficient of 0.3 significant at 0.04 level). Similar analysis of the GIS level of presence indicates the same set of associated factors. These factors make sense intuitively as larger acreages of forested and state owned land, as well as greater amounts of resources would seem to likely influence the level of GIT presence.



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The results differ for remote sensing, as state ownership, expenditures, and population are the most significant variables. This situation may indicate that states with greater populations have greater availability or exposure to remotely sensed data, which may in turn reflect private sector marketing priorities. No significant correlations were found for GPS. Overall, none of the relationships are particularly strong, but these findings warrant consideration for further investigation.

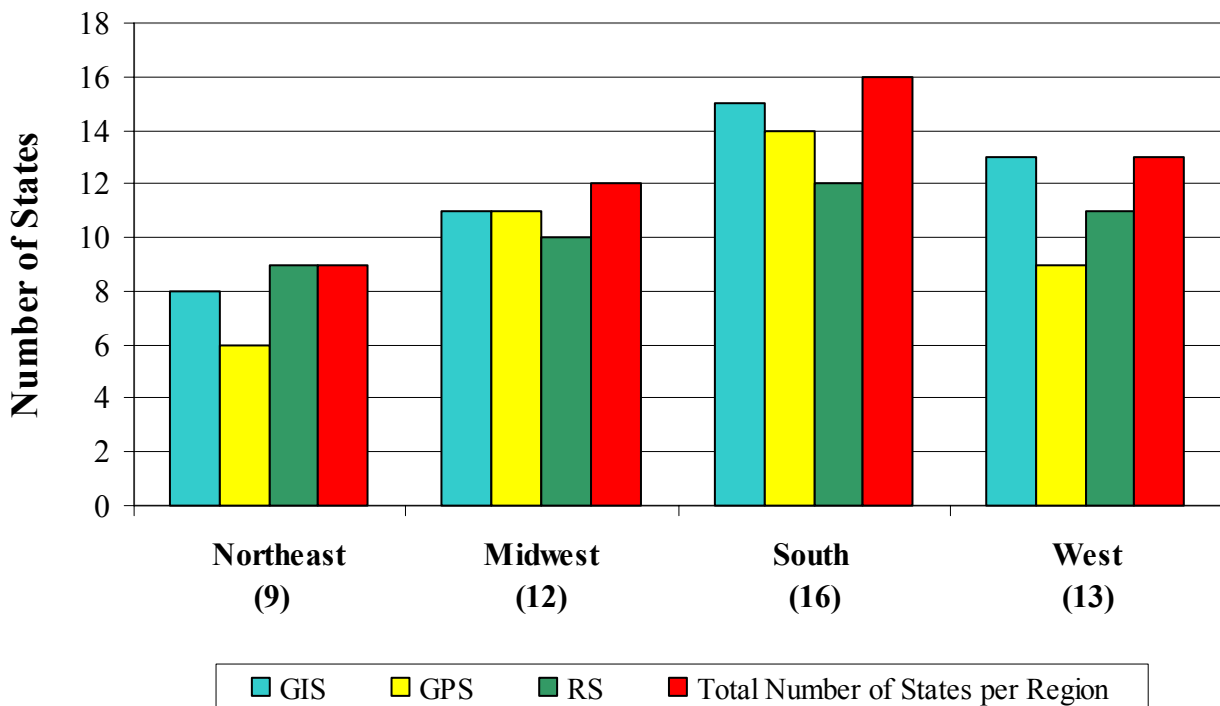
4.3 Remote Sensing Usage in SFOs

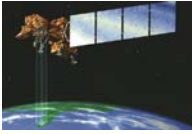
A leading focus of this investigation has been to ascertain and understand the presence and use of remote sensing in the nation's 50 SFOs. The vast majority of SFOs use some form of remote sensing. Only eight SFOs reported no usage, and

three indicated that other state agencies use it for forestry related applications. It is likely that almost all SFOs currently or formerly used aerial photography, particularly to manage forested lands. However, profile participants probably concentrated efforts on providing information about digital data given the emphasis of this project on newer data and technology. Particular efforts were made to determine the types of remotely sensed products that are being used. As shown in **Figure 4-6**, the results were categorized into five specific types of remote sensing that are defined in **Figures 1-1a and 1-1b** in Chapter 1.

Digital aerial data and satellite data were most often indicated as being used by SFOs. At least 33 or almost two thirds of the SFOs are known to be using digital aerial data. This usage is primarily in the form of digital orthophotos

Figure 4-5. Regional Use of GIT





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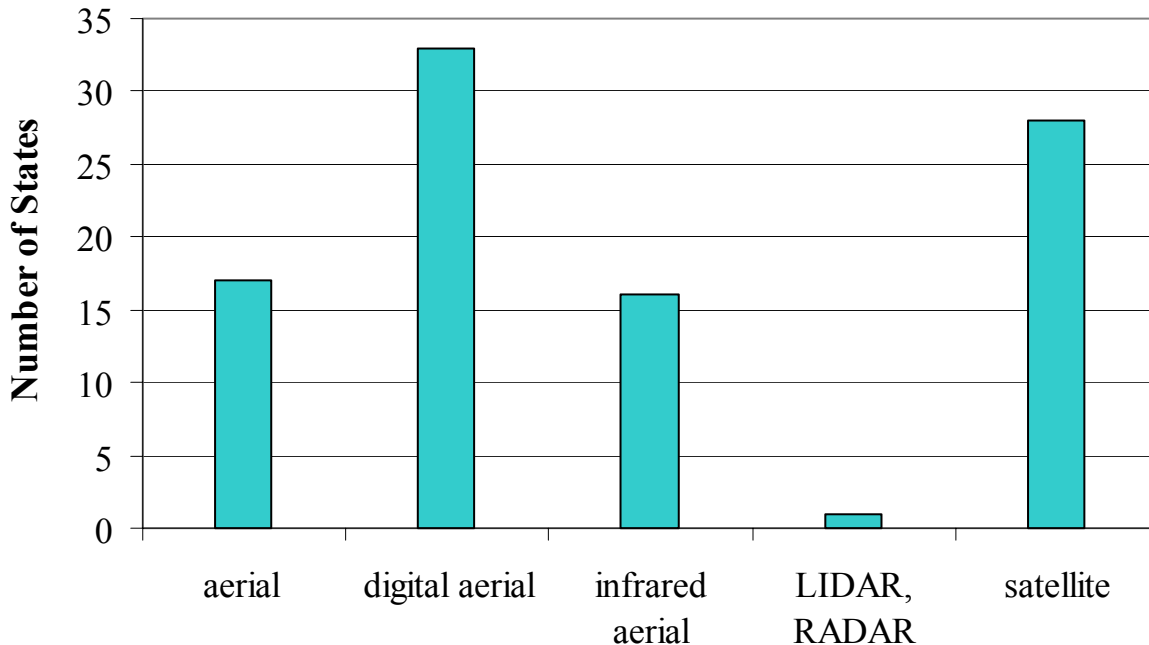
acquired with other agencies through the National Digital Orthophoto Program (NDOP) or through individual state digital orthophoto programs.

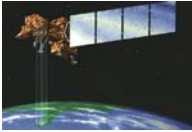
Satellite data was indicated as being used in 28 SFOs. LANDSAT TM data is most frequently used, although SPOT and IKONOS were also mentioned. This frequency of LANDSAT use is understandable since it has been available since the 1970s and is less costly than private sources of imagery. LANDSAT also is the data source in some nationwide datasets used by SFOs, such as by the federal interagency Multi Resolution Landscape Characterization (MRLC) Consortium as discussed in Chapter 2. It also is the primary imagery source in the federal Gap Analysis Program (GAP), which has been a state by state effort to identify species biodiversity within specific land areas (gaps) for conservation efforts. Several SFOs indicated use

of GAP data for landscape analysis as well as wildlife and habitat matters.

Reported uses of aerial photography and infrared aerial photography were very close, with 17 SFOs using aerial photography and 16 using infrared aerial photography. Aerial photography is used for various purposes, but it lacks the map-like character of digital orthophotography and it is not in a digital form, which allows easy incorporation into GIS. Infrared aerial photography is much more useful for interpreting and delineating vegetation types and identifying forest health problems and also has been used extensively by foresters (Bobbe 2002). An example is the Pennsylvania SFO's use of false-color infrared photography for delineating areas of conifer cover for winter wildlife habitat, as shown on the front cover of this report.

Figure 4-6. Remote Sensing Use by the 50 SFOs





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Figure 4-7. Application Categories, Types of GIT Used and Outside Users

The following definitions are used in Figures 4-8a, b and c; 4-9a, b and c; and 4-10a and b.

Forestry Applications of Remote Sensing and other GIT

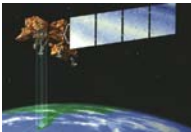
- A Forest Assessment, Planning, Protection, Conservation and Acquisition** - biomass and economic analysis, monitoring, Forest Legacy Program, Forest Practices Acts
- C Forest Characterization** - inventory efforts including Forest Inventory and Analysis program (FIA), stand typing
- H Forest Health** - insects, disease, other pest management
- WW Water, Wetlands and Watersheds**
- B Wildlife and Habitat** - including Gap Analysis Program (GAP)
- NR Other Natural Resources** - monitoring, assessment, visual impacts, analysis, planning
- L Land Cover and Landscape Ecology** - change analysis, forest fragmentation, Environmental Impact Statements (EIS), cumulative effects, criteria and indicators analysis
- SL State Lands** - timber management, reforestation, road management, and nursery management
- PL Private Lands** - oversight, regulation, taxation, assistance, management plans
- FE Fire and Emergencies** - mitigation, preparedness, response and recovery for disasters including fire, other weather phenomena such as ice storms, hurricanes, floods, etc.
- U Urban and Community Forestry**
- ED Economic and Rural Development** - forest products forecasting and marketing, other economic programs
- RC Recreation**
- CE Communications and Education** - public participation, outreach programs, workshops, Internet GIS

Types of GIT Used

G	GIS
P	GPS
RS	Remote Sensing
a	aerial photography
d	digital aerial data (including DOQs)
i	infrared aerial photography
l	LIDAR, RADAR
s	satellite

Forestry GIT Users Outside SFOs

*	Other state agency
#	University
&	Other organization (federal agency, NGO)



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Figure 4-8a. GIT Applications in All 50 SFOs

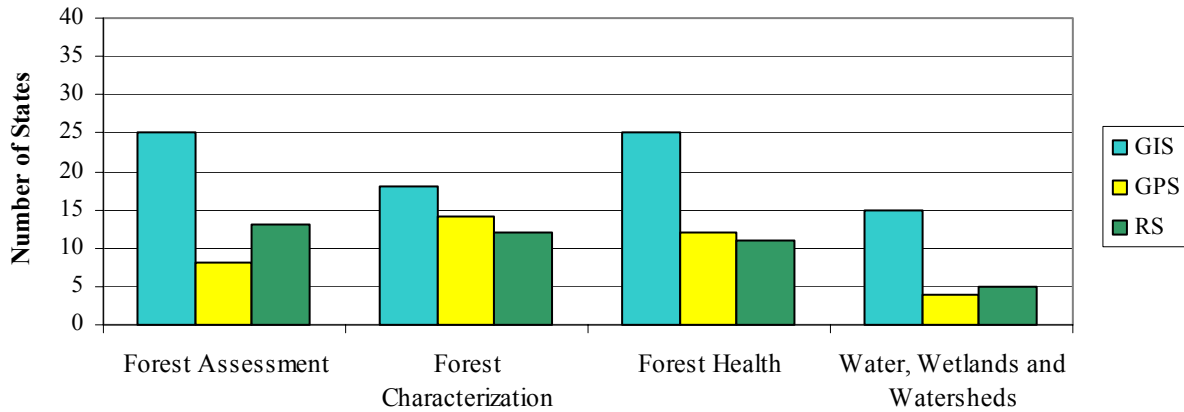


Figure 4-8b. GIT Applications in All 50 SFOs

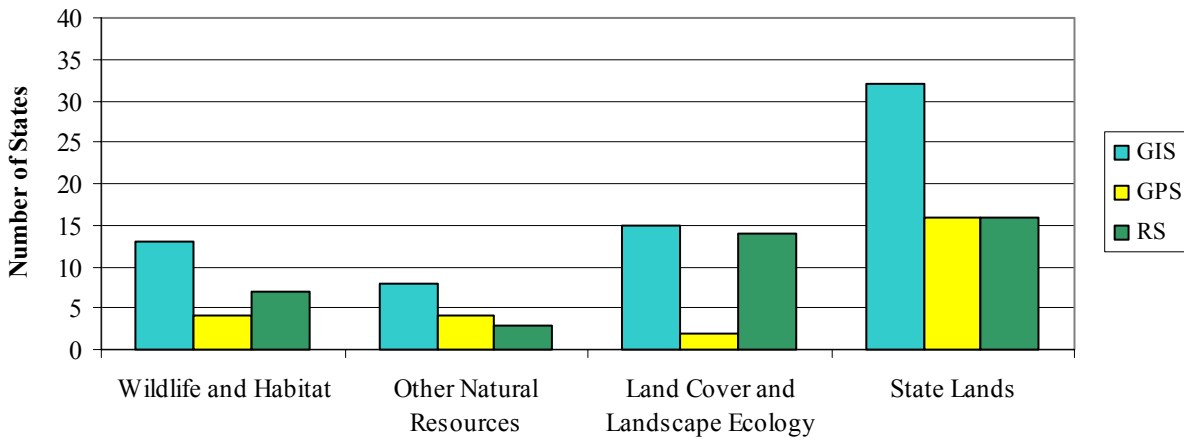
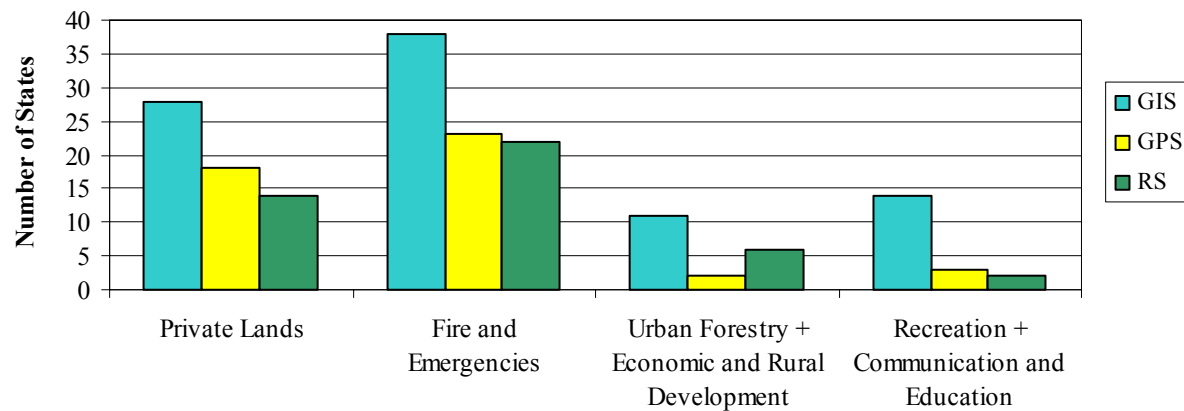
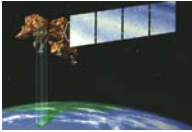
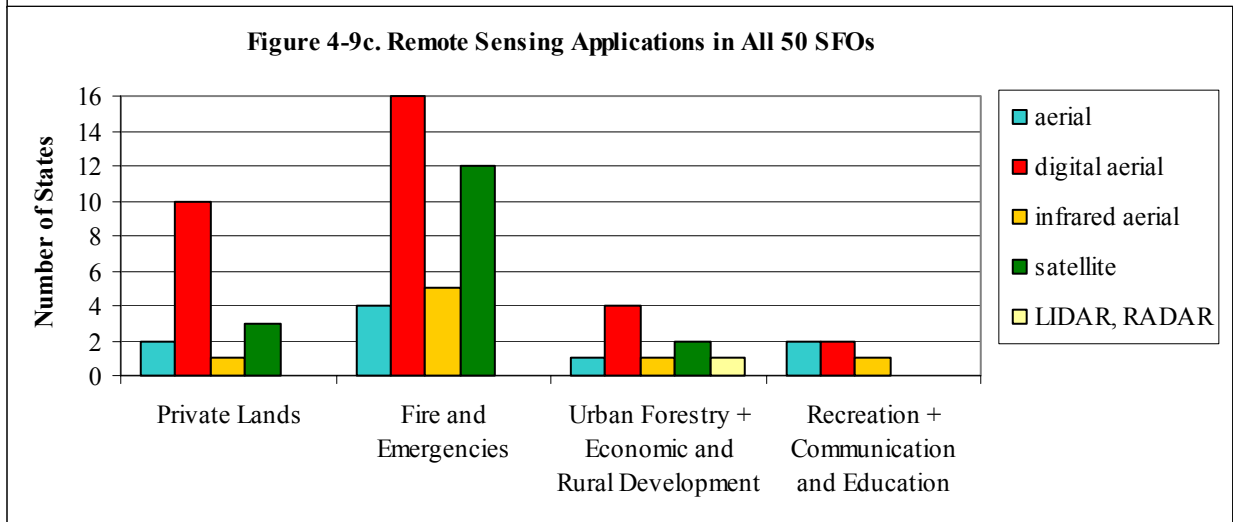
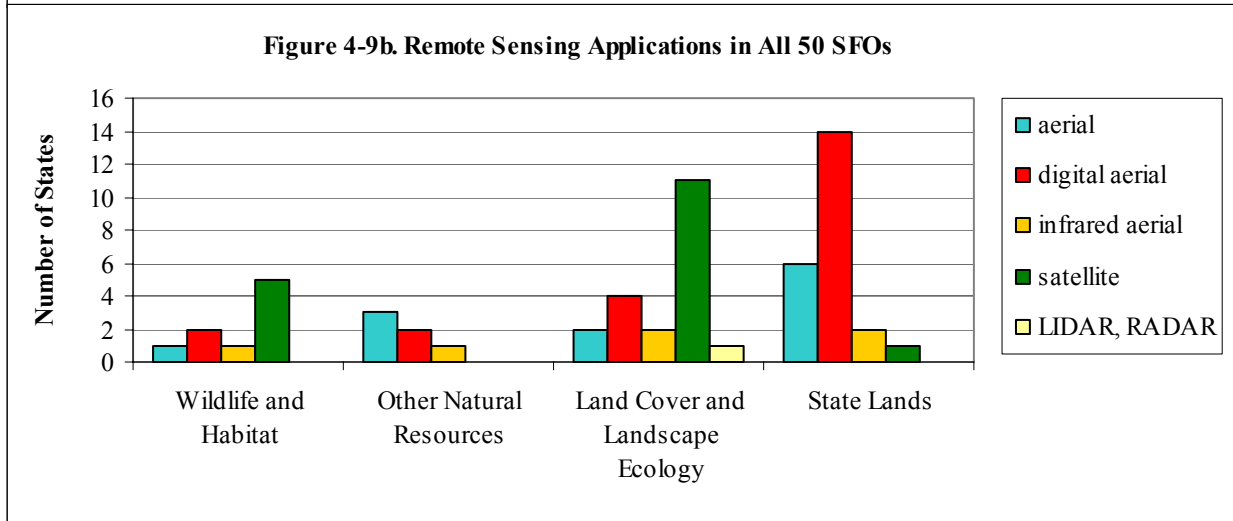
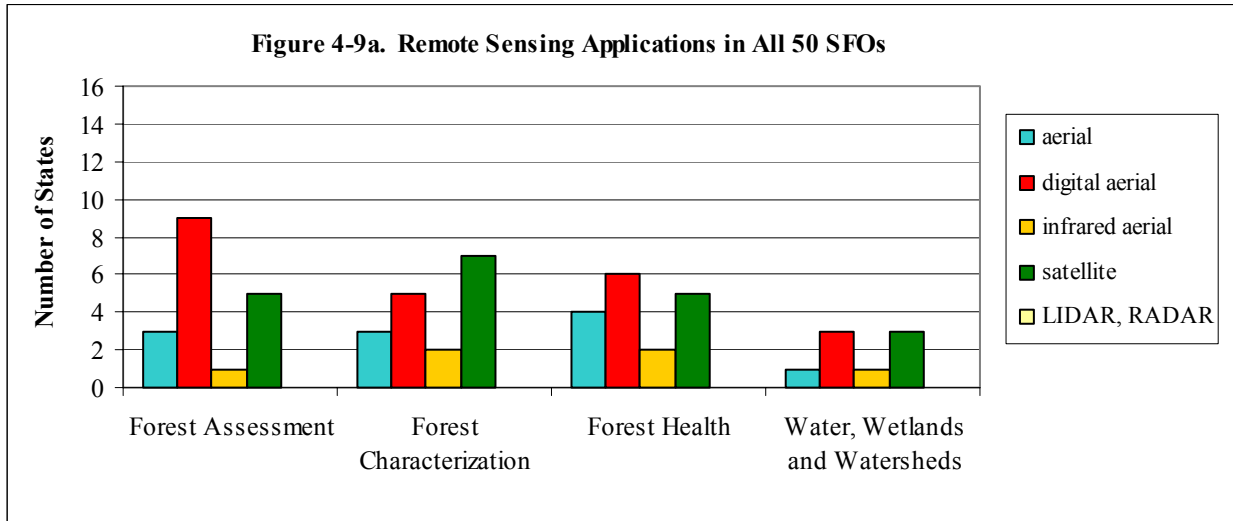


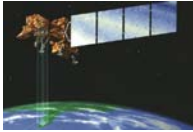
Figure 4-8c. GIT Applications in All 50 SFOs





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The least used forms of remote sensing in SFOs are LIDAR and RADAR. Only the Texas SFO indicated use of this technology at this time. However, several SFOs reported interest in LIDAR, and usage is anticipated to grow as costs continue to decline and applications become known. Some SFOs are active in LIDAR research and investigation. Many SFOs are observing others' work, such as at the University of Washington and the University of New Mexico's NASA Affiliated Research Center, which both have current LIDAR projects with forestry implications.

Further information about GIT use is included in Chapter 5, which addresses individual applications, and each profile's Section 2 in Appendix C.

4.4 Summary of Forestry GIT Applications

An important focus of the project has been to delineate specific types of remote sensing and other GIT applications. As shown in **Figure 4-7**, a set of 14 categories was determined based on thorough review of the profiles. All applications findings in Section 2 of the profiles were then classified and coded into these categories. Remote sensing and other GIT use vary for specific forestry applications. Some SFOs indicated using GIT extensively for several forestry applications, while others only reported usage for one or a few applications. Chapter 6 includes findings concerning how applications are conducted in an integrated manner or more separately, which varies by internal organizational approach to GIT.

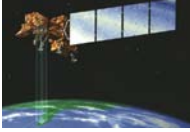
Figures 4-8a, 4-8b and 4-8c provide summary findings about the frequencies of GIS, RS and GPS applications reported by the 50 SFOs according to the 14 categories described indicated above. Given the specific project focus on remote sensing, the results for the same categories were also compiled for each of the

five types of remote sensing described above, as shown in **Figures 4-9a, 4-9b and 4-9c**. GIT applications results in the 50 profiles (in Appendix C), that were used to create these summary figures, are presented in detail in **Figures 4-10a and 4-10b**. Coding explanations in **Figure 4-7** were used for all of these figures. In addition to indicating all applications underway by each of the 50 SFOs, **Figures 4-10a and 4-10b** also indicate GIS, RS and GPS usage by other organizations outside the SFOs, such as state agencies, universities, federal agencies and others.

The summary results indicate that the most common uses of GIS, GPS and RS by SFOs are for Fire and Emergencies, State Lands, and Private Lands. These applications were also the strongest for use of digital aerial data, and in the case of Fire and Emergencies, for satellite data as well.

Though not the subject of analysis in this project, it appears that the frequency of applications generally corresponds to the most important missions and concerns of SFOs. Perhaps the earliest "driver" for GIT use in SFOs was to cost effectively manage state lands in order to maximize long term revenues to support state government, education and other functions. As shown in **Figure 4-8b** and discussed in Chapter 5, Section 5.6, and the profiles in Appendix C, this application is well represented with 32 states indicating use of GIS for this purpose. However, SFOs seem to be increasingly applying GIT to help accomplish many other, and almost all missions.

The recent increasing incidence and cost of fires seems to be well reflected in strong GIT usage (39). This level of usage may also reflect the availability of state or federal funding for such applications. While fire is the largest component of this category, some state foresters such as in New York and other eastern states indicate that emergencies serve as one of the best "drivers" to



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use new and better technology. For example, satellite data costs are more easily justifiable to quickly and cost effectively determine and address damages.

GIT has proven effective for fire and other emergency response, but the profiles reveal that some SFOs have also used the technology to mitigate and prepare for such events before they occur. For example, the California SFO's Fire and Resource Assessment Program (FRAP) has used GIT for several years to map fuels and fire risk, and conduct fire planning. Florida's SFO has an extensive project underway to precisely determine the location of and how to best address fire risk using detailed satellite data, GIS and extensive field work with GPS. Section 5.2 of Chapter 5, and the profiles in Appendix C provide more details about these efforts.

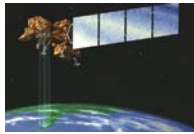
Stricter federal and state legislation and efforts to regulate or otherwise influence private forestry practices seems to be encouraging greater use of GIT by SFOs. Increasing attention to this issue is reflected in greater adoption and strengthening of State Forest Practices Acts as well as more programs to assist non-industrial land owners (Ellefson, Cheng, and Moulton 1995). Section 5.8 of Chapter 5 and the profiles in Appendix C provide examples of how SFOs are using GIT to encourage compliance and enforce Forest Practices Acts, but also to assist land owners, such as by using GIT to help develop stewardship plans. Several SFOs also use GIT in water resources applications (15), particularly in watershed protection efforts which in turn influence both public and private land management practices.

Efforts to understand and better manage forest conditions on state, private and all lands within a state have long been important uses of GIT by SFOs. The findings detail the frequencies and examples of SFO GIT usage for Forest Assessment, Forest Characterization and Forest Health, as summarized in **Figure 4-8a**. SFOs use

the two leading types of remote sensing, digital aerial data and satellite data, at similar levels for these applications. Several SFOs are using GIT as part of the Forest Inventory and Analysis (FIA) program with the U.S. Forest Service. Some SFOs, such as in Minnesota, Michigan and Wisconsin, have served as leaders in applying GIT to this program. Half of the SFOs use GIT for Forest Health, including aerial surveys and GPS to monitor insect damage and additional GIT to mitigate damage due to pests and disease.

The least frequent uses of GIS, GPS and RS were reported for applications such as urban forestry, economic and rural development, recreation, and communications and education. As a result, these four applications categories were collapsed into two groupings in **Figures 4-8c and 4-9c**. Although these applications also had the lowest frequency of overall RS use, digital aerial data was more commonly indicated for these applications than others. Texas's use of LIDAR for urban forestry is one of only two applications identified that use LIDAR.

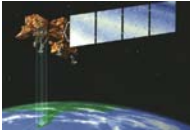
The next chapter provides an overview of all 14 GIS, RS and GPS forestry application categories, with examples from selected SFOs as extracted from the profiles in Appendix C.



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Figure 4-10a. GIT Applications in the 50 SFOs

		A	C	H	WW	B	NR	L	SL
1	Alabama		P	P					
2	Alaska	a,d,i	a,i,s	G,a,d,i,s	a,d,i	a,d,i	a,d,i	G,d,i,s	G,a,d,i
3	Arizona			G		(*G)			G,P
4	Arkansas	G,P		G,P	G,P,s	G,P,s			G,P
5	California	G,d,s	G,s	G	G,d			G,s	G
6	Colorado	G		(# G,d)		G			G
7	Connecticut	G						(* # & G,s)	
8	Delaware	G	G, P,a	G, P,a				(*G)	G, P,a
9	Florida	G			G	G			G
10	Georgia					(*G,s)			
11	Hawaii			G	G,s	G,s		G,s	
12	Idaho	G		G,P	G				G
13	Illinois	(*G,P)			(*G)	G, P	G,P	(*G,P,s)	G,P (*d)
14	Indiana			G,P					G (*G)
15	Iowa			G,P,d	(*G)				G,d
16	Kansas		P						
17	Kentucky		G,s					G,s	
18	Louisiana		P	(*G,P)	(*& G,s)	(*G,s)		(*& G,s)	
19	Maine	G,P			G,P	G			
20	Maryland	G	G		G	(* G,s)	G	(*G,s,l)	
21	Massachusetts	G		G		G	G	G	G
22	Michigan		G,s	G,a,s				G,s	
23	Minnesota	G,P,a,d	G,s	G,s	G,d,s	G,s	G,P,a,d	G,P,a,d	G,P,a,d
24	Mississippi	G,s	G,s (#& G,s)			G,s		G,s	G,P,d
25	Missouri	G	G	G,s	(*G,s)	(*G,s)		G,s	G,a,d,i
26	Montana		(*G)		(*G)				(*G)
27	Nebraska		G P,a,d			(*G,s) G,s			G,d
28	Nevada		P	G,P	G		P		P
29	New Hampshire	G,P,s						(# G,d,s)	
30	New Jersey		G,P	G,P	(*G,P,s)		G,P,s	G,s	G,P
31	New Mexico								G,P
32	New York	G (#P)	G,P,d	G,a,d,s	G			G,s	G
33	North Carolina	G,d	G,d	G, d					G,d
34	North Dakota							a	
35	Ohio						G	G,s	G
36	Oklahoma								P
37	Oregon	G, d,s			G		G		G
38	Pennsylvania	G,P	G,P	G,P	G,P	G,P		G,P	G,P
39	Rhode Island	a		(*G)			a		
40	South Carolina	G,P,d	G,P	i		(*G,s)			G,P,d
41	South Dakota		G,P,d	G					
42	Tennessee			G,P					G,a
43	Texas		G					G,d,i,l	
44	Utah	G,P,d		G,d	G, P	(# G,s)			G,P,d
45	Vermont	G,d		G					G,d
46	Virginia	G	P	G, P	G			G,s	G,P,d
47	Washington	G	G	G	G	G	G		G,P,d
48	West Virginia			G					G,P
49	Wisconsin	G,P,d	G,P,d,i,s	G,d		G,P,d		G,d,s	G,P,a,d,s
50	Wyoming		P	P					G,P,d



Chapter 4 Implementation of GIT in State Forestry Organizations

Figure 4-10b. GIT Applications in the 50 SFOs

		PL	FE	U	ED	RC	CE		GIS	GPS	RS
1	Alabama	P								P	
2	Alaska	(*G)	G,a,d,i,s			a,d,i			G		a,d,i,s
3	Arizona	G,P	G,P,s						G	P	s
4	Arkansas	G,P	G,P,s	G,P					G	P	s
5	California	G	G,P,d,s						G	P	d,s
6	Colorado		G						G		d,s
7	Connecticut	G							G		d,s
8	Delaware	G, P,a	G, P,a	(*G)			(*G)		G	P	a
9	Florida		G,d,i,s				G		G	P	d,i,s
10	Georgia	G,P (#G,s)	G,P						G	P	(*s)
11	Hawaii		G			G			G		d,s
12	Idaho	G	G,s				G		G	P	a,d,s
13	Illinois	G,P (*d)	(* G,P,d)				(*G)		G	P	(*d,s)
14	Indiana	(*G)	G	G,s	G,P,d				G	P	d,s
15	Iowa	G,d							G	P	d
16	Kansas									P	
17	Kentucky	G,P,d	G,P,d						G	P	d,s
18	Louisiana	P							G	P	(*s)
19	Maine	P	G,P,a				G		G	P	a,d
20	Maryland		G,s	G,s	G				G		(*l),s
21	Massachusetts		G	G					G	P	d,i,s
22	Michigan								G	P	a,d,i,s
23	Minnesota	G,P,d,s	G,d,s			G,P,a,d			G	P	a,d,s
24	Mississippi	G,P,d	G,P,d						G	P	d,s
25	Missouri	G,d							G	P	a,d,i,s
26	Montana		G						G		
27	Nebraska		G,d,s						G	P	a,d,s
28	Nevada	P	G,P						G	P	
29	New Hampshire		G,i						G	P	(*d),i,s
30	New Jersey	(*G,P)	G,P,d	G			G		G	P	d,i,s
31	New Mexico	G,P	(#& i)(#l) G,P,d,i,s						G	P	d,i,(*)l,s
32	New York	G,P	G, a,d,s			G			G	P	a,d,i,s
33	North Carolina	G,d	G,d						G		d,i
34	North Dakota	G	G						G		a
35	Ohio	G,P				G			G	P	s
36	Oklahoma	P	G,P	G,a,d					G	P	a,d
37	Oregon	G,d	G,P,d						G	P	a,d,s
38	Pennsylvania		G,P			G,P			G	P	d,i
39	Rhode Island						(*G)		* G		a
40	South Carolina	G,P,a,d	G,P,d,s	G					G	P	a,d,i,s
41	South Dakota	G	G,P,d						G	P	d
42	Tennessee	G	G,P						G	P	a
43	Texas		G	G,d,i,l			G		G	P	a,d,i,l
44	Utah	G,P,d	G,P,d	G, d					G	P	d,(*)s
45	Vermont	G,d					G		G		d
46	Virginia	G,s	G, P				G		G	P	d,s
47	Washington	G,s	G,P			G,P			G	P	d,i,s
48	West Virginia	G	G,P				G		G	P	
49	Wisconsin	G,i	G,P,d,i						G	P	a,d,i,s
50	Wyoming		P						G	P	d,i