Introduction

Chapter 1

INTRODUCTION

This is the tenth 'State of Forest Report' ('SFR') of the country. With this, India completes two decades of systematic and regular forest cover mapping on a biennial basis. Over the years, there have been advancements, both in the field of remote sensing technology and the interpretational techniques.

Remote sensing technology has emerged as an important tool for assessing the forest resource rapidly. The satellite provides the best synoptic view of the forest landscape. Through satellite data, it is possible to assess the forest cover broken down to density classes and the other land cover classes accurately. Using multi-date scenes supplemented with ground data, it is also possible to find broad types of forests (deciduous or evergreen). The remote sensing satellite data therefore has become very handy for stratifying the forests into homogenous sections which make the field inventory efficient, accurate and cost effective. Using very high resolution satellite data, it is also possible to discern isolated patches of trees and other tree resources outside forests.

In the first 'SFR' of 1987, the satellite data of Landsat having 80 m resolution was visually interpreted on 1:1 million scale. The minimum mappable area was 400 ha. In the present cycle, the data of Indian Remote Sensing Satellite Resourcesat-I (IRS-P6 sensor LISS-III) having resolution of 23.5 m has been digitally interpreted on 1:50,000 scale where minimum mappable area is 1 ha. This has helped in making the assessment more objective, and the analysis of the changes more accurate. The gaps/blanks in forests having more than 1 ha area which were earlier included in forest cover have been excluded. On the other hand, isolated forested patches of more than 1 ha area which were not captured earlier are included now. Further, maps being in digital form, it has become easy and fast to generate maps on any desired scale, of any specific area, for different users including State/UT Forest Departments (SFDs).

1.1 Two Decades of Forest Cover Assessment

It is to be noted that the actual forest cover of the country could be known for the first time in 1987 when assessment was completed with the satellite imagery and was published in 'SFR 1987.' Since then, Forest Survey of India (FSI) has been regularly assessing the forest cover of the country every two years. India is the first country in the world to start an operational system for monitoring forest cover. Brazil had started the same in the year 1989 for monitoring the forest cover of Amazon region only (50% of Brazil's area). Other countries such as Bolivia, Indonesia & Peru have initiated similar monitoring systems using satellite remote sensing imagery on a project basis.

Developments in the application of remote sensing

Table 1.1: Application of remote sensing technology in forest cover mapping over two decades

Assessment	Year	Data Period	Sensor	Resolution	Scale	Forest Cover (km^2)	%age of G.A.
I	1987	1981-83	LANDSAT-MSS	80 m	1:1 million	640,819	19.49
II	1989	1985-87	LANDSAT-TM	30 m	1:250,000	638,804	19.43
III	1991	1987-89	LANDSAT-TM	30 m	1:250,000	639,364	19.45
IV	1993	1989-91	LANDSAT-TM	30 m	1:250,000	639,386	19.45
V	1995	1991-93	IRS-1B LISSII	36.25 m	1:250,000	638,879	19.44
VI	1997	1993-95	IRS-1B LISSII	36.25 m	1:250,000	633,397	19.27
VII	1999	1996-98	IRS-1C/1D LISS III	23.5 m	1:250,000	637,293	19.39
VIII	2001	2000	IRS-1C/1D LISS III	23.5 m	1:50,000	653,898	19.89
IX	2003	2002	IRS-1D LISS III	23.5 m	1:50,000	677,816	20.62

technology in forest cover mapping in last two decades is presented in Table 1.1. It can be seen that besides improvement in the resolution of the satellite data and the scale of interpretation over the years, the gap between data period and assessment year has reduced with the introduction of digital image processing (DIP). Though the digital image processing was introduced in 1993, a complete switchover to this technology took place in the year 2001. It has now become possible to have one time data for the whole country and thus making the assessment specific to a reference year. For example, most of the data in the present assessment ('SFR 2005') pertains to November-December 2004. For the limited areas of North-East region and for A&N Islands, data of January-February 2005 was used due to non-availability of cloud free scenes.

Due to enhancement in the scale of interpretation (1:50,000), it has been possible to capture forest cover patches down to 1 ha. The increase in the forest cover in 2001 & 2003 assessments was partially due to the capture of such patches.

Digital interpretation has also made it possible to add one more canopy density class in the mapping of forest cover. Against the two density classes (dense forest between 40-100% and open forest between 10-40%) earlier, it is now possible to classify forest cover in three density classes (very dense between 70-100%, moderately dense 40-70% and open 10-40%) since 2003.

After reviewing the technological inputs in the forest cover assessments of the other countries, it appears that the spatial resolution and scale of interpretation currently used in India at the national and at the State level is optimal. Brazil currently uses 25 m spatial resolution whereas 250 m spatial resolution has been used in the project level assessments in other countries.

Necessary expansion in hardware and software infrastructure has taken place in FSI to make the switchover in technology possible.

1.2 Harmonization of Forest Cover of Previous Assessments

The experience gained and the technological advancement over the years has helped in improving the accuracy of interpretation, thus leading to revision of the previous assessments. A comparative account of the revised estimates on forest cover for the period starting from 1987 to 1995 after incorporating interpretational corrections was published in 'SFR 1997'. With the adoption of new technology in 2001 when the assessment for the entire country was done digitally on 1:50,000 scale, a large number of additional forested patches were captured. Since these patches were outside the areas of the previous assessments, they needed detailed ground verification. But the same could not be done comprehensively due to paucity of time and lack of human resource. As a result, many patches were wrongly interpreted. It has been possible to rectify these errors with detailed ground truthing in subsequent assessments, i.e., of 2003 and 2005. In addition, some rectification of the errors was done on account of radiometric and geometric errors of satellite data.

The quality of satellite data (IRS- P6, LISS III), which is available since 2003 is also found to be superior in terms of radiometry and shadow compared to that of IRS 1C/1D which FSI, was using until 2003.

The revised area figures of forest cover for 2001 and 2003 assessments are presented in Table 1.2 & 1.3 respectively.

1.3 Forest Cover in Recorded Forest Areas

FSI assesses the forest cover of the country irrespective of ownership, legal status and land use. The major portion of the forest cover, however, falls within the recorded forests. The area of the forest cover within the recorded forests can be known only when the geocoded maps / boundaries of the recorded forests are made available to FSI.

The State/UT Forest Departments (SFDs) are the custodians of the records, data and maps of the recorded

forest areas (which includes Reserved, Protected and Unclassed Forests). However, the SFDs generally have cadastral forest maps, which are not georeferenced. Although, Survey of India (SOI) toposheets show forest areas with double dotted lines and wooded lands as greenwash patches, these are usually based on surveys done several decades back and may be at variance with the current status of the forest boundaries.

Further, there exist disputes of forest boundaries with other land owning agencies in the States/UTs and demarcation of forest land on the ground are unclear. As such, many SFDs have difficulty in providing appropriate maps for

Table 1.2: Original and revised area figures of forest cover of 2001 assessment

(area in km^2)

State/UT	2001 Assessment					
	Dense		Open		Total	
	Original	Revised	Original	Revised	Original	Revised
Andhra Pradesh	25,827	24,385	18,810	18,810	44,637	43,195
Arunachal Pradesh	53,932	55,647	14,113	14,113	68,045	69,760
Assam	15,830	13,406	11,884	11,884	27,714	25,290
Bihar	3,372	3,027	2,348	2,348	5,720	5,375
Chhattisgarh	37,880	39,162	18,568	18,568	56,448	57,730
Delhi	38	52	73	73	111	125
Goa	1,785	1,255	310	310	2,095	1,565
Gujarat	8,673	6,434	6,479	6,479	15,152	12,913
Haryana	1,139	520	615	615	1,754	1,135
Himachal Pradesh	10,429	8,976	3,931	3,931	14,360	12,907
Jammu & Kashmir	11,848	10,497	9,389	9,389	21,237	19,886
Jharkhand	11,787	11,681	10,850	10,850	22,637	22,531
Karnataka	26,156	22,461	10,835	10,835	36,991	33,296
Kerala	11,772	9,629	3,788	3,788	15,560	13,417
Madhya Pradesh	44,384	42,401	32,881	32,881	77,265	75,282
Maharashtra	30,894	28,452	16,588	16,588	47,482	45,040
Manipur	5,710	6,673	11,216	11,216	16,926	17,889
Meghalaya	5,681	6,632	9,903	9,903	15,584	16,535
Mizoram	8,936	7,839	8,558	8,558	17,494	16,397
Nagaland	5,393	6,028	7,952	7,952	13,345	13,980
Orissa	27,972	28,178	20,866	20,866	48,838	49,044
Punjab	1,549	745	883	883	2,432	1,628
Rajasthan	6,322	4,497	10,045	10,045	16,367	14,542
Sikkim	2,391	2,362	802	802	3,193	3,164
Tamil Nadu	12,499	12,009	8,983	8,983	21,482	20,992
Tripura	3,463	5,267	3,602	3,602	7,065	8,869
Uttar Pradesh	8,965	5,997	4,781	4,781	13,746	10,778
Uttarakhand	19,023	18,439	4,915	4,915	23,938	23,354
West Bengal	6,346	6,045	4,347	4,347	10,693	10,392
Andaman & Nicobar	6,593	6,284	337	337	6,930	6,621
Chandigarh	5	9	4	4	9	13
Dadra & Nagar Haveli	151	149	68	68	219	217
Daman & Diu	2	2	4	4	6	6
Lakshadweep	27	12	0	0	27	12
Pondicherry	35	17	1	1	36	18
Total	416,809	395,169	258,729	258,729	675,538	653,898

Table 1.3: Original and revised area figures of forest cover of 2003 assessment

(area in km^2)

State/UT	2003 Assessment							
	Very Dense		Moderate Dense		Open		Total	
	Original	Revised	Original	Revised	Original	Revised	Original	Revised
Andhra Pradesh	23	130	24,356	24,221	20,040	20,061	44,419	44,412
Arunachal Pradesh	13,907	14,445	39,604	38,084	14,508	15,163	68,019	67,692
Assam	1,684	1,449	11,358	11,431	14,784	14,855	27,826	27,735
Bihar	76	80	2,951	3,034	2,531	2,459	5,558	5,573
Chhattisgarh	1,540	2,256	37,440	36,720	17,018	17,016	55,998	55,992
Delhi	0	0	52	54	118	120	170	174
Goa	0	55	1,255	1,095	901	1,014	2,156	2,164
Gujarat	114	114	6,231	6,073	8,601	8,627	14,946	14,814
Haryana	2	3	518	524	997	1,049	1,517	1,576
Himachal Pradesh	1,093	1,097	7,883	7,831	5,377	5,431	14,353	14,359
Jammu & Kashmir	2,102	2,135	8,395	8,394	10,770	10,744	21,267	21,273
Jharkhand	2,544	2,544	9,137	9,076	11,035	10,949	22,716	22,569
Karnataka	431	464	22,030	21,638	13,988	13,144	36,449	35,246
Kerala	334	1,024	9,294	8,637	5,949	5,934	15,577	15,595
Madhya Pradesh	4,000	4,251	37,843	36,899	34,586	34,995	76,429	76,145
Maharashtra	8,070	8,201	20,317	20,221	18,478	19,092	46,865	47,514
Manipur	720	930	5,818	5,595	10,681	10,734	17,219	17,259
Meghalaya	168	265	6,323	6,786	10,348	9,874	16,839	16,925
Mizoram	84	133	7,404	6,522	10,942	11,928	18,430	18,583
Nagaland	57	236	5,650	5,860	7,902	7,919	13,609	14,015
Orissa	288	487	27,882	27,712	20,196	20,154	48,366	48,353
Punjab	0	0	743	709	837	836	1,580	1,545
Rajasthan	14	14	4,482	4,454	11,330	11,353	15,826	15,821
Sikkim	458	498	1,904	1,912	900	852	3,262	3,262
Tamil Nadu	2,440	2,650	9,567	9,788	10,636	10,565	22,643	23,003
Tripura	58	58	4,988	4,972	3,047	3,093	8,093	8,123
Uttar Pradesh	1,297	1,297	4,699	4,682	8,122	8,148	14,118	14,127
Uttarakhand	4,002	4,002	14,420	14,409	6,043	6,049	24,465	24,460
West Bengal	2,303	2,302	3,742	3,774	6,298	6,313	12,343	12,389
Andaman & Nicobar	3,475	3,397	2,809	2,777	680	633	6,964	6,807
Chandigarh	1	1	8	8	6	6	15	15
Dadra & Nagar Haveli	0	0	145	130	80	91	225	221
Daman & Diu	0	0	2	2	6	6	8	8
Lakshadweep	0	0	12	15	11	10	23	25
Pondicherry	0	0	17	17	23	25	40	42
Total	51,285	54,518	339,279	334,056	287,769	289,242	678,333	677,816

assessing area within the recorded forests. In many cases, the area of the notified forest lands does not tally with that on the ground and also with the area computed from the maps available with the SFDs. There are also issues related to map projection system and datum in preparing correct maps compatible with ground which pose problems to SFDs. Thus, due to non-availability of the boundaries from the SFDs, it is not possible to provide the forest cover within the recorded forests.

Despite the above constraints, some States/UTs, viz., Andhra Pradesh, Kerala, Meghalaya and Dadra & Nagar Haveli have succeeded in providing the geocoded boundaries of their recorded forests. In respect of these States/UTs, forest cover and the change within and outside recorded forest area have been presented in the current 'SFR'.

It is hoped that with the application of GIS and GPS tools, generation of such maps would be convenient and geo-referenced forest maps for the whole country showing the latest boundaries of recorded forest areas would be available on 1:50,000 scale in due course of time.

1.4 Forest Plantation and its Impact on Forest Cover

One of the important objectives of establishing forest plantations in the country is to enhance the forest cover so that the national goal of 33% forest and tree cover is achieved besides producing wood and other products for meeting the needs of society and wood based industries.

Though the forestry plantations constituted an important component of the five-year development plans in the country since the beginning; large-scale plantations to the tune of more than a million ha per year started since 1979. The decade of 1980-90 has been the boom period for forestry plantations due to the launch of social forestry projects in several States. The annual rate of planting since 1990 has stabilized to about 1.5 million ha per year. It is to be noted that this area includes plantations raised by forest departments/corporations in Government and common land, and by all other agencies including farmers under 20 point programme of the Government of India. The area of about 35% of the total annual plantations has been computed from the number of seedlings distributed.

It is generally felt that these plantations will add to the forest cover to increase its extent in proportionate manner. It is, however, to be noted that all plantations do not survive. Some plantations are raised in degraded forests to improve the stocking, which would not result in a net increase of forest cover but will only improve the density of the forest class. There is also some fake reporting of plantation to meet the targets. Some of the fast growing, short-rotation species are clear felled and planted. Due to lack of proper accounting of these details, the accurate area of existing forest plantations by species, age class, locations at any reference year is uncertain and their exact contribution to forest cover is not known.

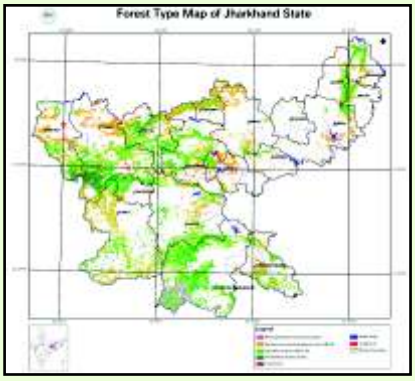
Further, young plantations (up to 5-6 years old) have small crown and low chlorophyll content in the foliage; therefore, they are not discernible on satellite images as forest/tree cover. The present 'SFR' has therefore not been able to take into account the existing area of the plantations raised since 1999-2000 (gross area 9.2 million ha) due to technological limitations.

1.5 National Forest Inventory

Forest growing stock (wood volume) has traditionally been a key indicator of forest capacity for wood production and its estimation has formed a major activity of forest resource assessment/inventory. In India, systematic forest inventory began in 1864 when the preparation of working plan started and has remained central to the forest management at divisional/district level.

The forest inventory on a relatively large area (catchment) basis using a statistically robust approach and aerial photographs began in 1965 when the Pre-Investment Survey of Forest Resources (PISFR) was launched in the

Box 1.1 Forest Type Mapping of India's Forests



Forest Survey of India has undertaken a project on mapping of forest types of India which is based on Champion & Seth classification. The project under the National Natural Resource Management System (NNRMS), aims at mapping of the forest types of India on 1:50,000 scale. The methodology used includes GIS analysis of the spatial layers such as rainfall, temperature, altitude zones, soil, thematic maps, interpreted remote sensing data and related attribute data sets. Taking district as a unit, extensive ground truthing covering all the forest types is being done for all the districts of the country. Consultation with the State Forest Departments and experts in the field is part of the methodology. This country wide exercise is expected to be completed by the end of year 2008.

country with FAO/UNDP assistance. The inventory in selected areas of the country was continued till 1981 when the PISFR was reorganized as FSI. Even after the creation of the FSI the field inventory remained the primary activity with a modified design covering the whole country. The total forest area inventoried until the year 2000 was about 69.2 million ha which included some areas inventoried twice. Thus, more than 80 percent forest area of the country was inventoried comprehensively in a period of 35 years.

A new National Forest Inventory (NFI) has been designed and adopted by FSI since 2002. The country has been divided into 14 physiographic zones and 60 districts randomly selected from these zones on probability proportional to size are inventoried in two years. About 8,000 sample plots are laid in forest areas distributed over the country in each cycle for field inventory. Now, it has been possible to generate a national estimate of growing stock on a two-year cycle. The first such estimate was published in 'SFR 2003.' As per design, the accuracy of the estimate in subsequent cycles will improve by integrating the data of previous cycles.

In addition to inventory of forests, Trees Outside Forests (TOF) resources are also inventoried concurrently to provide a national estimate of growing stock of TOF on a two year cycle. In this case also, about 9,000 sample plots are laid out in TOF areas. In the recent past TOF resources have gained importance because of their increasing role in meeting the needs of wood based industries and society.

1.6 World Forest Resources

FAO of United Nations has been assessing world's forest resources periodically since its inception in 1945. In the initial period, questionnaires were sent to all the countries to collect figures on forest areas, growing stock, increment and removals, etc. Besides assessing forest area, the availability of timber remained the main focus. The questionnaire-based assessment was discontinued in 1960's. The global assessment was started during 1980's, when the measurable parameters of forest resource were properly defined and standard estimation procedures were introduced. Besides using forest inventory data of countries to estimate the forest area, productive forest area and wood volume, experts' opinions were also employed as input to the 1980 assessment. In some countries, where reliable information was lacking, satellite images were manually interpreted to complete the assessment. The assessment of the deforestation rate in the tropical countries was one of the major concerns.

In 1990, there was further refinement in the methodology by using a model-based estimation for national level assessments; and remote sensing based sample survey of the forest area change in the tropics. The additional focus was on biodiversity and forest plantations. The definition of forest adopted in 1980, i.e., 20% crown cover for industrialized countries and 10% for developing/tropical countries was followed to ensure continuity of global assessments. The Forest Resource Assessment (FRA) 2000 adopted a common definition of forests globally, i.e., 10% canopy cover for all the regions of the world and made use of the national reports submitted by the country correspondents and continued with the remote sensing based sample survey over the tropics. The most recent FAO assessment, made in 2005 has followed the definitions and methods of 2000 assessment except the remote sensing survey part. The focus has been on thematic elements needed to monitor progress in sustainable forest management.

Because of the difference in approach and changes in definition of forest, the world forest resource estimates, as reported by FAO, have been changing over the periods on account of technical as well as real changes on the ground, as discussed in FAO Forestry Paper 147. The total forest area of the world reported in 1948 was 4 billion ha. In 1963, it was 3.8 billion ha. In 1990 it came down to 3.4 billion ha and after adopting a common definition of forests worldwide, the FRA 2000 reported the world forest area to be 3.869 billion ha, while FRA 2005 of FAO estimated the total area of the world's forests at 3.952 billion ha (more or less same as in 1948), which is about 30% of the total land area of the world. As per GFRA 2005, the top ten countries with the largest forest areas is depicted in Table 1.4, of these top ten countries, five countries, viz: Russian Federation, Brazil, Canada, USA and China account for more than half of the world's forest area.

It has been reported that the forest area continued to decrease but the rate of net loss slowed during 2000-2005. The largest net loss of forest was in South America (4.3 million ha per year). In Asian countries, there has been a slight net increase in the forest cover due to large-scale forest plantations in China. The forest cover in India is also reported to have increased slightly.

1.7 Proposed Future Activities

1.7.1 Refinement in Methodology of Forest Cover Assessment

FSI has been following the raster-based approach in forest cover mapping, since the satellite imagery is in the form of pixels (raster) which makes the interpretation quick. The raster based maps are, however, not fully compatible for GIS analysis; as a result, interpretation of the satellite data in each cycle has to be done independently. This also makes the changes in forest cover prone to interpretational errors.

FSI therefore proposes to switch over to a vector based approach in which forest cover would be mapped in polygons (vector) by defining clusters of pixels with boundaries. This will improve the cartographic presentation of the output, help map the changes more accurately and make the output available in GIS-ready format.

1.7.2 Forest Fire Monitoring

Substantial forest area of the country is annually damaged due to forest fires but there is no reliable data on it. The remote sensing technology has been found very effective in near real time detection of forest fire and monitoring of the burnt area. Currently the detection of forest fire is being done

by FSI on daily basis during the fire season and the concerned state governments are informed accordingly. However, there is no mechanism in place for assessing damages and mapping of the burnt areas by any institution at the national level.

Forest fire being a calamity of trans-border nature, FSI proposes to take up forest fire detection and monitoring as a major and regular activity for generating crucial and timely information for forest fire management and also to facilitate compensation for the damages to the affected states and persons. This will also help in development of time series database on forest fire occurrence and burnt areas, which will help in formulating proper policy and strategy to control forest fire by central and state governments.

Table 1.4: Top ten countries with the largest forest areas in 2005

Countries	Area in million ha
Russian Federation	809
Brazil	478
Canada	310
USA	303
China	197
Australia	164
Congo	134
Indonesia	88
Peru	69
India	68
Total World	3,952

1.7.3 Monitoring of Young Plantations

The present application of remote sensing for forest cover assessment is unable to assess the young plantations due to the low chlorophyll content in the foliage. As a result, the afforestation efforts in the country are not being reflected. Ministry of Environment & Forests has asked FSI to develop a monitoring mechanism for young plantations using high resolution satellite imagery. To achieve this objective, all the planting agencies (SFDs) will be requested to provide the details of their plantation giving geo-coordinates/locations/district area of plantation and species of the total plantation sites (patches). Appropriate number of sites (patches) will be selected on statistical principles. Based on the topology and terrain of the area, mostly LISS IV multispectral (Mx) scenes along with a few IKONOS or QuickBird scenes will be used to identify those patches and to calculate the area and to assess the success rate. This will be followed by extensive ground truthing.

1.7.4 Production and Consumption Studies

The accurate knowledge of production and consumption of wood and other forest produce forms the basis of rational planning of the forestry sector. Though a few States in India have undertaken wood balance study in last decades, there is no reliable estimate at the national level of all the forest products produced from different sources and their consumption by different users and wood based industries. FSI therefore proposes to undertake periodic studies on production and consumption of timber, fuel wood and other forest products at national level in association with the state forest departments.

Box 1.2 The Technical Advisory Committee of FSI

The Technical Advisory Committee (TAC) of the Forest Survey of India (FSI) was constituted by the Ministry of Environment & Forests, Government of India in November 2006 to review the technical activities of FSI and to provide guidance on the following:

a. The methodology followed by FSI for biennial forest cover assessment using remote sensing.
b. The methodology followed by FSI for forest inventory, for assessment of the trees outside forests (TOF) and for the assessment of non-timber forest products (NTFP).
c. The methodology for studies on production and consumption of timber, fuel wood and other forest products at national level every five years.
d. Development of spatial and non-spatial national forest database by linking FSI with the State/UT forest departments (SFDs).
e. Methodology for use of remote sensing, GIS and GPS in the preparation of management/working plans.

TAC includes members from Survey of India, Indian Institute of Remote Sensing (IIRS), National Sample Survey Organisation (NSSO), Space Applications Centre (Department of Space), State Forest Departments, Indian Agriculture Statistical Research Institute (IASRI), Wildlife Institute of India (WII), Indian Council of Forestry Research & Education (ICFRE), Indira Gandhi National Forest Academy (IGNFA), Ministry of Environment & Forests (MoEF) and FSI. The notification prescribes for holding at least one meeting of TAC every year.

Box 1.3 Near Real Time Monitoring of Forest Fires

FSI is monitoring forest fires of the country since 2004 using remote sensing based system developed by the University of Maryland (USA) and NASA viz MODIS Rapid Response System. The detection of forest fires is made on a daily basis through the website http://maps.geog.umd.edu. After collecting coordinates of the fire spots, FSI maps the forest fires through GIS analysis. The coordinates of all the forest fires are then sent to the respective State Forest Departments through fax and email for control during fire season. From the feedback received from SFDs, it has been found that the detected forest fires are correct on more than 95% points.