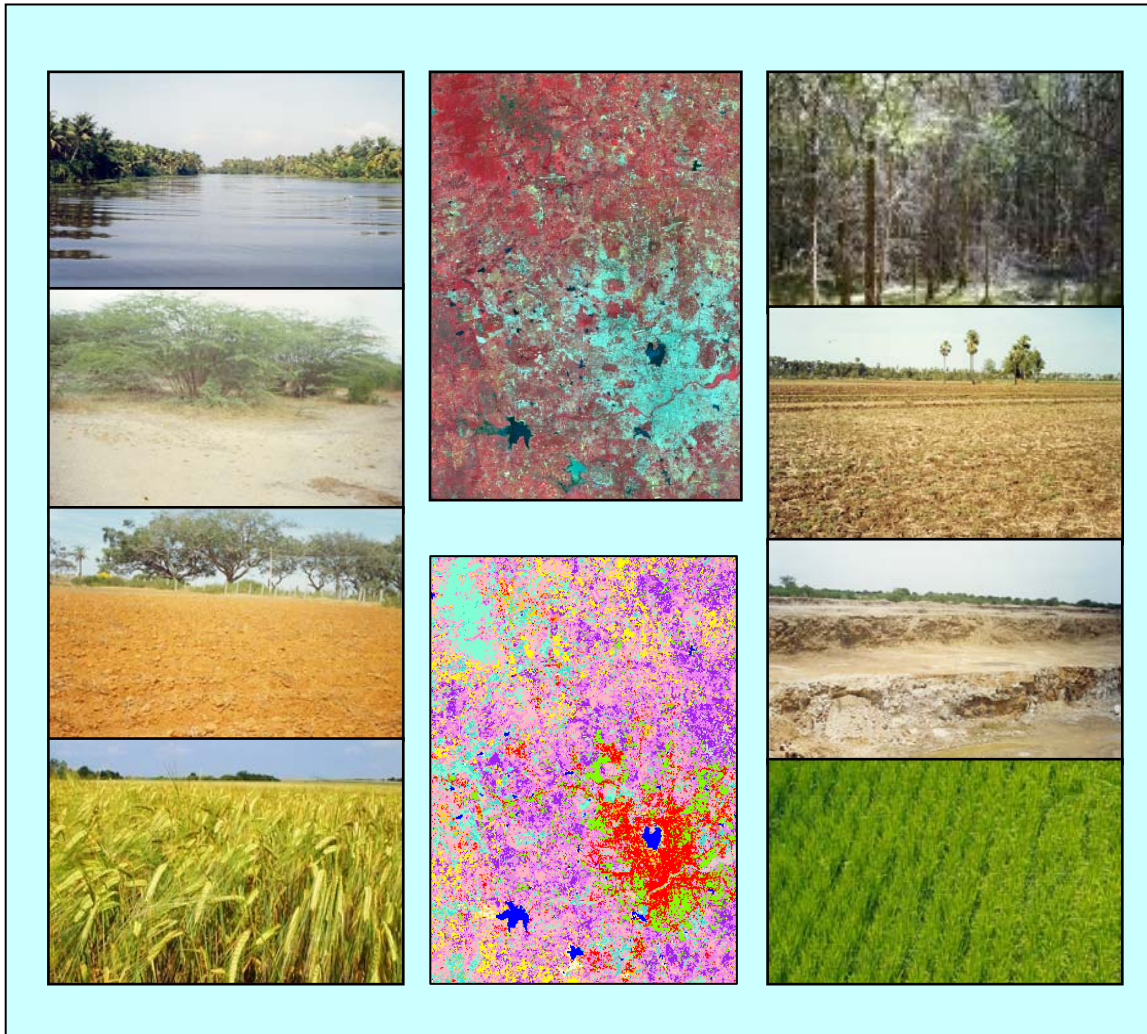


NATURAL RESOURCES CENSUS

NATIONAL LAND USE AND LAND COVER MAPPING USING MULTITEMPORAL AWiFS DATA (LULC-AWiFS)

PROJECT MANUAL



nrsa

Remote Sensing & GIS Applications Area
NATIONAL REMOTE SENSING AGENCY
Department of Space, Government of India
HYDERABAD

APRIL 2005

NATURAL RESOURCES CENSUS

**NATIONAL LAND USE AND LAND COVER MAPPING
USING MULTITEMPORAL AWiFS DATA (LULC-AWiFS)**

PROJECT MANUAL



**Remote Sensing & GIS Applications Area
NATIONAL REMOTE SENSING AGENCY
Department of Space, Government of India
HYDERABAD**

April, 2005

Document Control

Document Number	NRSA/RSGIS- AA / NRC/ NLULCAWiFS/ PROJMAN/R01/APRIL05
Title	Natural Resource Census National Land Use and Land Cover Mapping using Multitemporal AWiFS (LULCAWiFS) - Project Manual
Type of Document	Technical Document
Number of pages	
Author(s)	Project Team
Reviewed by	Project Director, NRC-LULC-AWiFS
Approved by	DD(RS&GIS-AA), NRSA
Abstract	To implement the project uniformly at all work centres and to maintain high quality standards through out project period this project manual is prepared. The manual discusses about project background, geo-rectification of satellite data, radiometric normalization of satellite data, data classification and mapping, geo-database and quality evaluation procedures.
Controlled by	One Master copy with Project Director NRC-LULC-AWiFS and DD, RS&GIS-AA, NRSA
Distribution	Dy Project Directors of the project and their team members.
Reproduction Rights	This report and its contents are the property of National Remote Sensing Agency (NRSA) and shall not be reproduced in part or whole without the written permission of Director, NRSA.

PREFACE

To meet the increasing demands of population, tremendous pressure is being exerted on the natural resources for more food production, energy and water requirement etc. Natural resources, being finite implies more intensive use of land and depletion of resources at a much faster rate. Continuous exploitation of natural resources is the major reason for degradation of our environment leading to deforestation, soil salinity, water logging, soil erosion, desertification floods, droughts and species extinction. An important issue is to bring a balance among economic development, conservation of resources and ecology. In this regard reliable assessment and monitoring of land use and land cover (LULC) enables understanding the dynamic changes, and proper management of the natural resources especially agricultural production, conservation of surface water bodies and forests, reclamation of waste lands, coastal management, and urban planning, etc.

State-of-art technologies, Remote Sensing and Geographical Information System, offer great scope to generate and update the LULC information in spatial format rapidly at frequent intervals. This helps in proper monitoring of the resources and environment. In this context, Natural Resources-Census (NR-Census) Programme has been taken up by the Department of Space under the National Natural Resources Management System (NNRMS). The programme envisages mapping and inventory of natural resources using IRS images and generation of natural resources repository.

As part of this, a project on LULC mapping on 1 : 250,000 scale using multitemporal IRS-P6 AWiFS satellite data on annual basis is launched. This project is going to generate digital spatial and temporal database on 19 different LULC classes and also net sown area statistics of different cropping seasons. I hope this database is going to be a valuable and timely information for various types of users in the country and enables to undertake integrated studies addressing socioeconomic and ecological issues.

Implementing the National level LULC assessment using multitemporal IRS-P6 (Resourcesat-1) AWiFS data poses a challenge in terms of standardizing the geodatabase, mapping methodology, and calls for an integrated effort of ISRO/DOS Centres. The project team has prepared this *Project Manual* addressing various aspects of the project. I am confident that this document will bring uniformity in the execution of the project by the different centers involved in the project. Further, this manual is expected to be quite handy for the scientists involved in the project as it addresses briefly general overview and concepts of the methodology envisaged.

Director, NRSA

Date: April, 2005

PROJECT TEAM

GEO-RECTIFICATION TEAM		
Deputy Project Director	Shri Ch.Venkateswara Rao	NRSA, Hyderabad
Principal Scientist	Mrs Sai Veena Suresh	NRSA, Hyderabad
Co-Principal Scientist	Mrs A.Rebecca Swarna	NRSA, Hyderabad
Co-Principal Scientist	Mrs Latha James	NRSA, Hyderabad
Co-Principal Scientist	Shri P. Satyanarayana	NRSA, Hyderabad
CLASSIFICATION AND MAPPING TEAM		
Deputy Project Director	Dr M.S.R. Murthy	NRSA, Hyderabad
Co-Principal Scientist	N. Seshadri Sekhar	NRSA, Hyderabad
Region –1 (South)	Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Maharashtra , Goa, Andaman & Nicobar Islands, Lakshadweep and Pondichery	
Principal Scientist	Dr T Ravisankar	NRSA, Hyderabad
Co-Principal Scientist	Dr K.V.Ramana	NRSA, Hyderabad
Co-Principal Scientist	Shri Milind Wadodkar	NRSA, Hyderabad
Region –2 (North Central)	Bihar, Chattisgarh, Jharkhand, Madhya Pradesh, Orissa & West Bengal	
Principal Scientist	Dr S.V.C.Kameswara Rao	NRSA, Hyderabad
Co-Principal Scientist	Shri K Srinivas	NRSA, Hyderabad
Co-Principal Scientist	Dr Manoj Raj Saxena	NRSA, Hyderabad
Region –3 (North Eastern)	All North Eastern States & Sikkim	
Principal Scientist	Dr K.V.S.Badrinath	NRSA, Hyderabad
Co-Principal Scientist	Dr G.Ravi Shankar	NRSA, Hyderabad
Co-Principal Scientist	Shri K.Neelakantan	NRSA, Hyderabad
Region –4 (North)	Haryana, Himachal Pradesh, Jammu & Kashmir, Punjab, Uttaranchal & Delhi	
Principal Scientist	Dr M.C.Porwal	IIRS, Dehra Dun
Co-Principal Scientist	Dr Pawan Joshi	IIRS, Dehra Dun
Co-Principal Scientist	Shri Milap Punia	IIRS, Dehra Dun

Region –5 (West & UP)	Gujarat, Rajasthan, Uttar Pradesh, Damna & Diu, Dadra & Nagar Haveli	
Principal Scientist	Dr D.Dutta	RRSSSC-Jodhpur
Co-Principal Scientist	Shri S. Pathak	RRSSSC-Jodhpur
Co-Principal Scientist	Dr Rakesh Paliwal	RRSSSC-Jodhpur
GEO-DATABASE CREATION TEAM		
Deputy Project Director	Dr Y.V.S.Murthy	NRSA, Hyderabad
Principal Scientist	Shri M.V. Ravi Kumar	NRSA, Hyderabad
Co-Principal Scientist	Shri A.Ravi Kumar	NRSA, Hyderabad
Co-Principal Scientist	Shri A. Lessle	NRSA, Hyderabad
QUALITY EVALUATION TEAM		
Deputy Project Director	Dr J.R.Sharma	RRSSSC-Jodhpur
Principal Scientist	Shri Vinod Bothale	RRSSSC-Jodhpur
Co-Principal Scientist	Dr S.Jonna	NRSA, Hyderabad
Co-Principal Scientist	Smt. Rajashree Bothale	RRSSSC-Jodhpur
Co-Principal Scientist	Shri M.A.Fyzee	NRSA, Hyderabad
Co-Principal Scientist	Dr Rajeev Jaiswal,	EOS, ISRO Hqrs., Bangalore

PROJECT DIRECTOR		
Dr P.S. Roy, Deputy Director, RS&GIS - AA, NRSA		

ACKNOWLEDGEMENTS

At the outset I would like to express our sincere gratitude and gratefulness to Shri.G. Madhavan Nair, Chairman, ISRO for initiating National level assessment of land use and land cover (LULC), an important study from national perspective on annual basis using data from latest Indian Remote Sensing Satellite - Resourcesat.

I am thankful to Dr. R.R. Navalgund, Director, National Remote Sensing Agency and Chairman, Natural Resources Repository, for his overall guidance, encouragement and suggestions in bringing about this project manual for execution of the project.

I am also thankful to Dr. V. Raghavaswamy, Group Director, Land Use and Urban Studies Group and Dr.R.Nagaraja, Head, Land Use Division of NRSA for their suggestions on technical content of the manual. I am also thankful to Dr. K.M.M. Rao, Deputy Director-Data Processing Area, D.S. Jain, Group Director, Data Processing Group, Shri Arokia Das, Head, NRSA Data Center, for constant support.

Acknowledgements are also due to Shri.V.Sundararamaiah, Scientific Secretary, ISRO and Dr.V.Jayaraman, Director, Earth Observations Systems, ISRO, Bangalore for their cooperation and support towards formulation of the project. Shri.K.Mukund Rao, Dy Director, ISRO, HQ, Bangalore, has played an important role in co-ordination and provided support which is duly acknowledged.

I thank all the Deputy Project Directors of the Project for their valuable inputs for this document. I thank sincerely all participating scientists in the project who have contributed technical inputs for bringing out this document. I hope, this project Manual will facilitate implementing the project uniformly at all work centres and enable to maintain high quality standards through out the project period.

Place: Hyderabad
Date: April, 2005

(P.S. Roy)
Project Director &
Deputy Director (RS&GIS-AA)

EXECUTIVE SUMMARY

Spatial accounting and monitoring of land use and land cover (LULC) systems like agriculture, surface water bodies, waste lands, forests etc. has become essential for the sustainable utilization of natural resources. Considering this need and potential of IRS AWiFS sensor in monitoring the natural resources, National level LULC mapping project is taken up as part of NNRMS – DOS programme with the following objective:

National Level LULC mapping on 1: 250,000 scale using multi-temporal AWiFS datasets to provide on annual basis, net sown area for different cropping seasons and integrated LULC map at the end of each year starting from 2004 - 07. The following approach is envisaged for the project:

- Use of multi temporal AWiFS data covering Kharif (Aug – Oct), Rabi (Jan- Mar), Zaid (April- May) seasons to address spatial and temporal variability in cropping pattern and other land cover classes. Supplementing cloud and quality affected AWiFS datasets with WiFS/MODIS.
- Georeferencing of multi temporal datasets with LCC projection and WGS 84 datum. Conversion of all satellite datasets into TOA reflectance data to minimize temporal variability.
- Adoption of hierarchical decision tree classifier to effectively account the variability of temporal datasets and bring out reliable classification outputs. Use of legacy datasets on forest cover, type, wastelands and limited ground truth as inputs for classification and accuracy assessment.
- Develop geodatabase standards to address retrieval and storage of different data inputs and outputs, designing meta data elements relevant to different types of data, automated output production and interactive querying.
- Implement process based QAS to regulate the data flows and outputs as per the standards.
- Develop ‘Project Manual’ to maintain uniformity of work and implementation document to monitor the progress.
- Generate Net Sown Area statistics at state level for different cropping seasons and Integrated LULC map at the end of year.

The manual has brought out sequential steps to be followed in execution of different processes of the project, quality standards to be adhered at different stages of a process, various data flows and linkages between different processes of the project. The manual also addresses briefly general overview and concepts of the methodology envisaged to enable the participating scientists to understand the background.

CONTENTS

	Particulars	Page No.
	Preface	iv
	Project Team	v
	Acknowledgements	vii
	Executive Summary	viii
	List of Figures	xi
	List of Tables	xi
Chapter 1	INTRODUCTION	1-13
	1.1 Background	1
	1.2 Experiences in regional scale LULC mapping	2
	1.3. LULC Assesment – An Indian experience	3
	1.4. Multi-temporal satellite datasets – Classification Approaches	7
	1.4.1 Parametric classification approaches	7
	1.4.2. Non parametric Approaches	8
	1.4.3. Neural Networks	8
	1.4.4. Decision Trees	9
	1.5. Objective	10
	1.6. Approach	10
	1.7. Users perspective	11
Chapter 2	GEORECTIFICATION OF SATELLITE DATA	14-23
	2.1. Satellite data : AWiFS	14
	2.2 Preprocessing of satellite data	15
	2.2.1. Geometric correction	15
	2.2.2. Atmospheric correction	16
	2.2.3. Radiometric correction	17
	2.3. Projection standards	17
	2.3.1. Study-1	17
	2.3.2. Study-2	18
	2.3.3. Parallels for entire India	19
	2.4. Product specifications	19
	2.5. Reference database	19
	2.5.1. AWiFS reference database	19
	2.5.2. Sample reference data	19
	2.5.3. Naming scheme	20
	2.6. Methodology	21
	2.7. Procedure	23
	2.8 Quality parameters	23

Chapter 3	AT-SATELLITE REFLECTANCE COMPUTATION	24 - 26
	3.1 Gain and Offset calibration	24
	3.2 Sun angle and distance correction	24
Chapter 4	CLASSIFICATION AND MAPPING	27 - 42
	4.1. Input data	27
	4.2. Mapping legend	29
	4.3. Ground truth collection	29
	4.4. Analysis of satellite data	37
	4.5. Accuracy assessment	40
	4.6. Quality check of classification	42
	4.7. Mosaic and area statistics	42
Chapter 5	GEODATABASE	43 - 60
	5.1. Spatial framework	43
	5.2. Data categories and sources	45
	5.3. Naming conventions	46
	5.4. Data capacities	48
	5.5. Compatibility with NRR/NSDI metadata content	50
	5.5.1. Metadata	51
	5.6. Geodatabase architecture and organisation	52
	5.7. Security and Access control	54
	5.8. Data services, Visualization and customization	58
	5.9. Deliverables	59
Chapter 6	QUALITY EVALUATION	61 - 67
	6.1. QAS for project planning	61
	6.2. QAS for georectification	61
	6.3. QAS for thematic classification and statistics	65
	6.4. QAS for geodatabase creation	66
	6.5. QAS for hard copy generation and statistics	67
	6.6. Responsibilities	67
	References	68 -71
	Annexure I - VI	I-XXXVI
	Annexure I	II
	Annexure II	VI
	Annexure III	VII
	Annexure IV	VIII
	Annexure V	XI
	Annexure VI	XVIII

LIST OF FIGURES

No	Particulars
Fig. 1	Broad framework for project approach
Fig. 2	Detailed methodology
Fig. 3	AWiFS scenes layout covering the whole of India
Fig. 4	Sample AWiFS reference
Fig. 5	AWiFS reference map
Fig. 6	Generation of reference AWiFS data
Fig.7	Flow chart of generation of the product
Fig. 8	TOA reflectance image generation using AWiFS data sets
Fig. 9	Example Crop calendar of important kahrif / rabi crops (Andhra Pradesh)
Fig.10	Sampling Frame work
Fig. 11	Field sampling scheme
Fig. 12	Example of decision tree
Fig.13	Schematic diagram of the approach for decision tree classification
Fig. 14	Overview of geodatabase creation
Fig.15	Storage allocation of different data categories
Fig.16	Categories of data sets in geodatabase
Fig.17	Geodatabase ingest process
Fig.18	Map template – LULC-AWiFS project
Fig.19	QAS for geodatabase rectification
Fig.20	QAS for geodatabase classification
Fig.21	QAS for geodatabase creation

LIST OF TABLES

No	Particulars
Table 1	Values of Lmax and Eo for each band
Table 2	Satellite data for different seasons
Table 3	Legend for land use / land cover classification
Table 4	Data categories and sources of generation
Table 5	GIS vector, tabular data and their sources of generation
Table 6	Data categories and their disk capacities requirement
Table 7	Access to NAS information
Table 8	Standards for georectification
Table 9	Standards for classification
Table 10	Standards for geodatabase

CHAPTER –1**INTRODUCTION****1.1 Background**

India is bestowed with valuable natural resources consisting of forests, mineral deposits, wetlands, rivers, surface water bodies and vast areas of agriculture serving the needs of around a billion population and varied ecological functions. Due to increase in population, industrialization and with large variations in climate and natural disasters, the natural resources management has become very complex. Since independence the population has increased by 284 per cent (363 to 1033 m) and food grain production by 386 percent (51 to 196 mt). On the other hand, 260 m population still lives below the poverty line. The country has 150 Million ha of agricultural area and about 24% GDP is met from the agricultural production. The highly water dependent crop production systems are sensitive to monsoon climate, droughts and cyclones etc. and as well suffers from unscientific irrigation/ fertilization practices as well as pest attacks. Apart from this, trend of switching to commercial non-food grain crops is a cause of concern. While food grain production increased only by 1.7 times over the last two decades, non-food grain production quadrupled during the same period.

The forests, which are mostly of tropical and sub tropical in nature, constitute 64 million hectare and are most sensitive to biotic and climatic factors. The forest vegetation is present in four major ecological zones (Himalayas, Vindhyan, Eastern and Western Ghats) covering different altitudinal and latitudinal regions and their composition is regulated by the monsoon regimes and spatial variability in climate. The forest vegetation is largely disturbed because of the increasing rate of deforestation due to unsustainable extraction of timber, fuelwood and fodder as well as forestland conversions. It is estimated that the timber requirements, which was 68,857 mt in 1980, would rise to 181,270 mt by 2025. Fuel wood stands as the main stay of energy resource for 70% of Indian population and 125 mt are extracted annually. In addition over half of the live stock population (270 million) depend on forest for grazing resources and NTFP worth of Rs. 6.5 – 20 billion is met annually from forest.

The surface water resources support wide ranging natural and manmade biological systems, hence, play a key role in better management of natural resources. The increased urbanization and abnormal trends of precipitation are severely infringing the overall existence of surface water resources and wetlands across the country. Such seasonal and perennial water bodies serving as backbone of crop production need to be monitored to attain sustainable management of water resources.

Apart from these utilitarian resources, wastelands assume significant proportion of land use pattern amounting to 67 m ha out of which cultivable wastes constitutes around twenty per cent. The productive use of this resource would add to the economic and ecological amelioration of the system. Advent of huge planting efforts to harness potential of wastelands across country would require effective and regular monitoring of re-greening efforts, to develop better planting schemes and understand limitations.

Studies so far conducted in our country are limited in scope, as they cater for base line data towards regional planning and evaluation. The national spatial databases enabling the monitoring of temporal dynamics of agricultural ecosystems, forest conversions, and surface water bodies etc. are lacking. These kinds of databases are primarily important for national accounting of natural resources and planning at regular intervals. Land use and land cover mapping addressing Kharif, Rabi and Zaid crops, greening of wastelands, seasonality of wetlands/surface waterbodies, forest vegetation and other high temporal land use practices using satellite remote sensing data can provide a reliable database. In this context the census of natural resources - land, water, soils, forests and other elements – conducted in a systematic manner and with a repeat cycle to depict changes and modifications as a “snap-shot” of the country’s status of natural resources is realized as an urgent need.

1.2 Experiences in Regional Scale LULC Mapping

Varied experiences with regard to LULC mapping have been reported from different continents employing moderate to coarse resolution datasets often in tandem with ancillary databases. The National Mapping Program, a component of the U. S. Geological Survey (USGS), mapped LULC maps based on aerial photography acquired by NASA and the USGS during the 1970's and 1980's. The data was manually interpreted and LULC polygons were compiled onto 1:250,000 base USGS maps. The Anderson hierarchical classification scheme used with this data had nine major categories and several detailed level 2 classes.

Experience in China, depict compilation of a 1:1 million scale atlas of Land Use Map of China as the first land-use map for 1991 covering the entire territory of China. Mapping was based on field surveys, satellite images and aerial photos; classes were regrouped into 20 major land-use classes in the digital map (Wu, 1991). Another database of China, the “Temperate East Asia Land-Cover Database (TEAL)” used 1992 NOAA-AVHRR 1-km remote sensing information and existing land cover maps developed using traditional geographical techniques. The database was developed to understand land use changes in East China.

The National Land-Cover Database (NLC) project of South Africa aimed to produce a standardized land-cover database for all of South Africa, Swaziland and Lesotho. The land-cover database was derived (using manual photo-interpretation techniques) from a series of 1:250,000 scale geo-rectified on seasonally standardized, single date LANDSAT Thematic Mapper (TM) satellite imagery captured principally during the period 1994-95. It is based on broad-level thematic classes provided on GIS based vector format and that can be adapted further to suit individual user requirements.

The Global Vegetation Monitoring unit of the JRC, ISPRA, Italy has produced a new global landcover classification for the year 2000, in collaboration with over 30 research teams from around the world. The project was carried out to provide accurate baseline land cover information, a harmonized land cover database over the whole globe to the

International Conventions on Climate Change, the Convention to Combat Desertification, the Kyoto Protocol etc. GLC,2000 dataset is a main input dataset to define the boundaries between ecosystems such as forest, grassland, and cultivated systems. In contrast to former global mapping initiatives, the GLC,2000 project is a bottom up approach to global mapping. In this project, more than 30 research teams have been involved, contributing to 19 regional windows. Each defined region was mapped by local experts, which guaranteed an accurate classification, based on local knowledge. The mosaicing of 21 regional products, and the translation to a standardised global legend, made it possible to create a consistent global land cover classification based on regional expert knowledge.

Recent exercise of National Land Cover Database for United States known as “Multiresolution Land Characterisation 2001 (MRLC 2001)” has attempted to create an updated pool of Landsat 5 and 7 satellites to generate land cover database (National Land Cover Database 2001). The efforts covered aspects of providing consistent land cover database as well as to provide a portable data framework useful in several applications. The database included satellite images, elevation model and terrain products, per pixel estimates of percent imperviousness, percent tree canopy and 29 land cover classes. Classification rules, confidence estimates and metadata were also included in the database.

Another recent attempt on global LULC vegetation is use of MODIS data as one of the critical global data sets. The classification includes 17 categories of land cover following the International Geosphere-Biosphere Program (IGBP) scheme. The set of cover types includes eleven categories of natural vegetation covers broken down by life form; three classes of developed and mosaic lands, and three classes of non-vegetated lands.

1.3. LULC Assesment – An Indian Experience

In India the information on LULC in the form of thematic maps, records and statistical figures are inadequate and do not provide an up to date information on the changing land use patterns and processes. Over the years, the efforts made by the various Central / State Government Departments, Institution / Organizations etc., is sporadic and often efforts are duplicated. In most the cases, as the time gap between reporting, collection and availability of data is more, the data often becomes out-dated. However, the organizational efforts in publishing maps, reports and statistical data by various central, state and and other local agencies are noteworthy.

The Indian experience on use of satellite data for LULC analysis mainly comes from studies conducted at National Remote Sensing Agency (NRSA) in collaboration with different agencies. Realizing the need for an up to date nationwide LULC maps by several departments in the country, as a prelude, a LULC classification system (with 24 categories up to Level-II, suitable for mapping on 1:250,000 scale) was developed by NRSA, DOS, taking into consideration the existing land use classification adopted by NATMO, CAZRI, Ministry of Agriculture, Revenue Department, AIS & LUS etc. and the details obtainable from satellite imagery. The classification system provided the

conceptual frame-work after discussions with nearly 40 user departments / institutions in the country and 22 fold classification system which was adopted for Nationwide LULC Analysis.

Nationwide LULC Analysis for Agro-Climatic Zone Planning

District-wise LULC analysis of all the 15 agro-climatic zones, using the 22 fold LULC classification system was completed using 1988 – 89 satellite data sets. IRS - LISS-I data of kharif (July-October) 1988 and Rabi (November– March) 1989 were used to generate details of crop land in kharif and rabi seasons, the area under double crop, fallow lands, different types of forest, degradation status, wasteland, waterbodies etc. NRSA along with Regional Remote Sensing Service Centres (RRSSC's), State Remote Sensing Centres and other institutions completed this task using hybrid methodology i.e., visual as well as digital methods. Out of 442 districts in the country, 274 districts are analyzed using visual techniques and remaining 168 districts by digital techniques. Planning Commission of India was the main user for this project.

National Wastelands Inventory Project (NWIP)

Until recently, no attempt had been made to prepare map showing different types of wastelands in India. The area reported by various government agencies on the extent of wastelands varies from 38 M Ha. to 175M. Ha. In 1985, NRSA/Department of Space prepared wasteland maps of all states and union territories at a 1:1 million scale. The total area of wastelands in the country during 1980 – 1982, estimated through this study was about 53.3 million ha or 16.2 per cent of the area of the country.

In 1985, National Wastelands Development Board (NWDB) was setup with the objective of rehabilitating 5 million ha of land each year for fuel wood and fodder production through a massive programme of seeding and afforestation. This programme required a very reliable database that provided details on the type, extent, location and ownership of wastelands. Confronted by varying estimates of the extent of wasteland, including the NRSA figure based on remote sensing, it became evident that the NWDB had to provide precise definitions of the various categories of wasteland. The Technical Task Force established by the NWDB proposed a classification system consisting of thirteen categories of wasteland.

Subsequently waste land mapping on 1 : 50,000 scale was taken up in five phases and about 5000 wasteland maps covering the country were prepared. Methodology developed based on pilot studies were used for the identification and delineation of different types of wasteland using enlarged satellite data. Both Landsat Thematic Mapper (TM) and Indian satellite (LISS-II and LISS-III) data were used for mapping purposes. Hybrid methodology i.e. both visual and digital techniques were used to extract the wastelands thematic details. About 63.87 million ha (20.17 per cent) have been estimated as wastelands through this study.

Forest / Vegetation cover analysis

Using Landsat MSS data of 1972-75 and 1980-82 periods, NRSA (1983) carried out vegetation mapping on 1:1 million scale for the entire country, which showed a substantial decrease in forest cover. Subsequently, Forest Survey of India (FSI), Ministry of Environment and forests (MOEF) carried out mapping of India for the year 1981-83 which was published in the year 1987. Since 1987, the forest cover of the country is being assessed biennially by Forest Survey of India (FSI) using remotely sensed data. FSI has carried out 8 such surveys using satellite imagery of the periods 1981-83 , 1985-87 , 1987-89, 1989-91, 1991-93, 1993-95 and 1996-97. The total forest cover amounts to only 19.39 per cent of the geographical area of the country as per the latest available report of FSI.

Land Cover Mapping using Spot-Vegetation for South Central Asia

Under Global Land Cover (GLC) 2000, Indian Institute of Remote Sensing (IIRS), Dehradun, India has carried out a study for South Central Asian Region as part of this programme. The study has been executed with a participation of network support from countries like China, Sri Lanka, Myanmar, Thailand, Bhutan, Nepal and Bangladesh. The study has produced LULC map for South Central Asian Region using SPOT-4 VEGETATION and other ancillary information.

Biome level characterization of Indian Vegetation (IRS– WiFS Data)

Realising the potential of the IRS – WiFS datasets for regional level mapping, the assessment of phenological growth of vegetation in forest eco system has been attempted under ISRO-GBP programme by Indian Institute of Remote Sensing (IIRS), Dehradun . The climatic data with bio geographic map is used to delineate the biomes in the Indian Sub continent.

Vegetation type mapping

As part of landscape level biodiversity characterization project (DOS-DBS supported programme) vegetation type mapping of NE regions and Western Ghats on 1 : 250,000 scale was done using IRS-LISS-III satellite data. Central India, Eastern Ghats and East coast are being mapped on 1 : 50,000 scale using IRS P6, LISS-III satellite data

Vegetation and land use and land cover (IRS WiFS data)

Realizing the importance of LULC over a period of time, regional level mapping has been attempted in India using IRS WiFS data to bring out causes, rates, magnitude, patterns and trends in landscape changes. Earlier studies have demonstrated substantial contribution of RS and GIS techniques to map spatial distribution of important habitats

Integrated Mission Sustainable Development(IMSD)

This is one of the important projects carried out by Department of Space(DOS). It was initiated in 1987 as ‘Integrated Study to Combat Drought’. Under this project different thematic maps viz., LULC, Hydrogeomorphology, Soils, Slope etc. were generated on 1 : 50,000 scale and integrated to derive locale specific prescriptions called action plans for sustainable development of land and water resources. The entire work was carried out in three phases covering 175 districts in different agro-climatic zones covering about 84 million ha. or 25% of the total geographical area (NRSA,2002).

NRIS project

DOS has initiated this project in continuation to IMSD and the digital databases are being prepared for various themes. In this project the standards for database design, structure, theme content and codification were evolved. This project is being implemented in 17 states and all important natural resources including the LULC are being mapped on 1: 50,000 scale using IRS-LISS III data.

Integrated Resources Information System for Desert areas(IRIS-DA)

This is one of the recent projects carried out at NRSA(2002-2005) for Ministry of Rural Development(MRD). It covers parts of four states – Rajasthan, Karnataka, Gujarat and Haryana. In this project all thematic maps of natural resources are prepared on 1: 50,000 and the action plans for land and water resources development are generated. The LULC theme was mapped upto Level-III classes. In this project the action plans were generated using fuzzy logic and output were generated through an automatic software programmes developed.

Wetlands of India

This project is being carried out by SAC, Ahemdabad with the objective of mapping all the wetlands (like marshes, swamps, open water bodies, mangroves, tidal flats etc.) on 1: 250,000 scale for most of the states and on 1: 50,000 scale for few small states and UTs. This project was sponsored by Ministry of Environment and Forests, Government of India. Wetland delineation and mapping has been done using IRS-LISS I/II data of 1992/1993. The total wetland area has been estimated to be 7.6 M ha(excluding Paddy, Rivers and Canals)

Land Use / Land Cover inventory under NR Census

Before taking up of national level NR Census Mission, proto type districts studies were taken up to develop legends for mapping various themes, standardization of methodology including digital data base creation and generate census statistics for various natural resources. Prototype studies were done using 1999-2001 databases to understand the degree and magnitude of changes over a period of 5 years. DOS had contacted line departments under each theme to address above points and to create awareness in them.

The different themes addressed are geomorphology, soils, land degradation, LULC, wet lands, vegetation types and forest crown density, snow and glaciers. Prototype districts were selected based on diverse terrain types, physiography, agro-climatic zones etc. in the country. They are Guntur district, Andhra Pradesh. (NRSA), Mergerita block, Tinsukia district, Assam (NRSA, Hyderabad & NESAC, Shillong), Dehra Dun district, Uttaranchal (IIRS, Dehra Dun), Hassan district (RRSSC – Bangalore) and Bangalore district, Karnataka (EOS, Bangalore), Part of Ladakh district, Jammu and Kashmir (RRSSC, Dehradun), Gurgaon district, Haryana (RRSSC, Dehra Dun and HRSAC, Hissar), Jhalawar district, Rajasthan (RRSSC, Jhodpur), North Sikkim district, Sikkim (RRSSC - Kharagpur and Dehra Dun), Chandrapur District, Maharashtra (RRSSC, Nagpur), Vasai Taluk, Thane District, Maharashtra (RRSSC- Nagpur and MRSAC), and Lakhpat Block, Kachchh District, Gujarat (SAC).

1.4. Multi-temporal satellite datasets - Classification Approaches

Multitemporal satellite datasets are used as primary inputs for generation of spatial databases on temporally variant LULC classes. This becomes more relevant when developing regional and national level databases as the LULC classes exhibit varied spatial/temporal characteristics across larger geographical gradients. Hence the extraction of LULC information using multitemporal datasets become a complex process due to inherent heterogeneities involved in the datasets and LULC classes. Several parametric and nonparametric digital classification approaches were used to classify multitemporal datasets.

1.4.1. Parametric classification approaches

Townshend et al. (1987) performed supervised classifications on composited NDVI GAC (Global Area Coverage) data for South America. While they did not validate their results with test data, they found that accuracy for the training sites improved substantially with the increase in the number of images included in the time series. Koomanoff (1989) used annually integrated NDVI values to generate a global vegetation map using NOAA's Global Vegetation Index product (GVI). This work represents nine vegetation types and does not rely on the seasonality of the NDVI. Reed et al. (1994) and DeFries et al. (1995) have developed and used multi-temporal phenological metrics to derive land cover classifications from AVHRR data. Lambin and Ehrlich (1996a, 1996b) have found that using a time series of the ratio of surface temperature to NDVI provides a more stable classification than NDVI alone, primarily by isolating interannual climatological variability.

Loveland et al. (1991, 1995) have produced land cover maps using the International Geosphere-Biosphere Programme (IGBP) classification and Seasonal Land Cover Region (SLCR) classification systems for North America. These maps were based on one year of monthly composited AVHRR-LAC data to generate an unsupervised classification of land cover types for the conterminous United States. The resulting clusters were further stratified based on ancillary environmental data such as elevation

and ecoregion. Class labels were assigned based on the temporal curves of the clusters as well as a large number of ancillary sources. Global land cover at 1-degree resolution for 11 land cover classes has been achieved by DeFries and Townshend (1994), Friedl and Brodley (1997), Friedl et al. (1999), and Gopal et al. (1996). These global land cover maps are based on the agreement of the maps of Matthews (1983), Olson (Olson and Watts 1982; Olson et al., 1983) and Wilson and Hendersen-Sellers (1985).

1.4.2. Non parametric approaches

To overcome difficulties in conventional digital classification that uses the spectral characteristic of the pixel as the sole parameter in deciding to which class a pixel belongs to, new approaches like context classifiers, decision tree classifiers, neural network algorithms etc. are being developed. In the contextual classification, by considering a pixel in the context of its neighboring pixels classification is performed to improve the classification accuracy. Other ancillary data may also be incorporated in order to improve the classification like incorporating a digital elevation model. Another technique is Fuzzy classification in which each pixel is assigned a number for each class, ranging from 0 to 1, which indicate the proportions of the different classes which have contributed to the observed spectral signature. A limitation to this program is that the number of end-members that can be employed must be less or equal to the number of input bands. Thus, if the six reflective Landsat TM bands are used, a maximum of six classes can be employed. Neural network and decision tree classifiers are widely used as nonparametric tools.

1.4.3 Neural Networks: The use of Neural network classification algorithms are increasing in remote sensing. Unlike the maximum likelihood classifier, they do not rely on the assumption that data are normally distributed. A surface class may be represented by a number of clusters in a feature space plot rather than a single cluster. Remotely-sensed datasets processed by neural network-based classifiers have included images acquired by the Landsat Multispectral Scanner (MSS) (Benediktsson et al., 1990; Lee et al., 1990), Landsat TM (Yoshida and Omatu, 1994), synthetic aperture radar (Hara et al., 1994), SPOT HRV (Tzeng et al., 1994) AVHRR (Gopal et al., 1994) and aircraft scanner data (Benediktsson et al., 1993). A number of these studies have also included topography ancillary data (Carpenter et al., 1997), and texture. Many studies have been directed toward recognition of land cover classes, which have ranged from broad life-form categories (Hepner et al., 1990) to floristic classes (Fitzgerald and Lees, 1994).

The bulk of neural network classification work in remote sensing has used multiple layer feed-forward networks that are trained using the back propagation algorithm based on a recursive learning procedure with a gradient descent search. However, this training procedure is sensitive to the choice of initial network parameters and to over fitting (Fischer et al., 1997). The use of Adaptive Resonance Theory (ART) can overcome these problems. Networks organized on the ART principle are stable as learning proceeds, while at the same time they are plastic enough to learn new patterns and improves especially the overall accuracy of classification of multi-temporal data sets (Gopal et al., 1994, Fischer et al., 1997). Recent MODIS based land cover classification uses a class of

ART neural networks called fuzzy ARTMAP, for classification, change detection and mixture modeling.

1.4.4 Decision Trees: Decision tree classification techniques have been used successfully for a wide range of classification problems. These techniques have substantial advantages for remote sensing classification problems because of their flexibility, intuitive simplicity, and computational efficiency. As a consequence, decision tree classification algorithms are gaining increased acceptance for land cover classification problems, particularly at continental to global scales. Among the advantages of decision trees that are particularly useful for remote sensing problems are their ability to handle noisy and missing data (Quinlan, 1993). More commonly, the classification structure defined by a decision tree is estimated from training data using a statistical procedure.

A variety of works have demonstrated that decision trees estimated in this type of supervised fashion provide an accurate and efficient methodology for land cover classification problems in remote sensing (Friedl and Brodley, 1997; Hansen et al., 1996; Swain and Hauska, 1977). Lloyd (1990) employed a binary classifier based on summary indices derived from a time series of NDVI data. These phytophenological variables included the date of the maximum photosynthetic activity, the length of the growing season, and the mean daily NDVI value. The variables were fed through a binary decision tree classifier that stratified pixels based first on the date of the maximum NDVI, then the length of the growing season and finally on the mean daily NDVI. DeFries et al. (1998) used decision trees to map land cover using the 8 km AVHRR pathfinder data set with encouraging success. Similarly, Friedl et al. (1999) recently demonstrated that decision trees provide a robust classification methodology for land cover mapping problems at continental to global scales.

As part of GLC 2000 each regional partner used the VEGA2000 dataset, essentially composed of 14 months of daily 1-km resolution satellite data acquired over the whole globe from the VEGETATION sensor onboard the SPOT4 satellite and delivered as multi-channel daily mosaics. For each day of the period, all channels are available, i. e. 4 spectral channels (blue, red, near infrared and short wave infrared), the NDVI, 4 angle channels, 1 status map and 1 time grid file. Data are top of canopy reflectances re-mapped to a lat-long grid. Each pixel is 1/112 degree in size. Each partner also used the Land Cover Classification System (LCCS) produced by FAO and UNEP, which ensured that a standard legend was used over the globe. The hierarchical classification system followed with these datasets allowed each partner to choose the most appropriate land cover classes which best describe their region, whilst also providing the possibility to translate regional classes to a more generalised global legend. The inputs for classification include: (i) EOS land/water mask (ii) nadir BRDF-adjusted Reflectance (iii) spatial texture derived from Band 1 (red, 250-meter) (iv) directional reflectance information at 1 km (v) MODIS Enhanced Vegetation Index (EVI) at 1 km (vi) snow cover at 500m (vii) land surface temperature at 1 km and (viii) terrain elevation information. These data are composited over a one-month time period to produce a globally consistent, multi-temporal database on a 1-km grid as input to classification and change characterization algorithms. Land cover classes are produced by processing the

32-days database using decision tree and artificial neural network classification algorithms.

Biome level Characterisation of Indian vegetation using Multitemporal IRS WiFS data was done. Distinctive phenological profiles of land covers like coniferous forest, dry deciduous forest, temperate forest, sub-alpine, alpine meadows, orchards, agriculture types were used for classifying land cover categories. The methods included maximum NDVI used in tandem with distinct peaking season to understand ‘greenwave’ of land cover elements. The land cover categories were assessed in integration with bioclimatic spatial layers to arrive at biome maps.

1.5. OBJECTIVE

The foregoing discussion has highlighted the need for spatial accounting and monitoring of LULC systems like agriculture, surface water bodies, waste lands, forests etc. for the sustainable utilization of natural resources of our country. Considering this need and potential of IRS AWiFS sensor in monitoring the natural resources, National level LULC mapping project is taken up as part of NNRMS – DOS programme with the following objective.

National Level LULC mapping on 1: 2,50,000 scale using multi-temporal AWiFS datasets to provide on annual basis, net sown area for different cropping season and integrated LULC map at the end of each year addressing cropping patterns and other LULC classes starting from 2004 - 07.

1.6 APPROACH

- Use of multi temporal AWiFS data covering Kharif (Aug –Nov), Rabi (Jan-Mar), Zaid (April- May) seasons to address spatial and temporal variability in cropping pattern and other land cover classes. Supplementing cloud and quality affected AWiFS datasets with WiFS/MODIS.
- Georeferencing of multi temporal datasets with LCC projection and WGS 84 datum. Conversion of all satellite datasets into TOA reflectance data to minimize temporal variability.
- Adoption of hierarchical decision tree classifier to effectively account the variability of temporal datasets and bring out reliable classification outputs. Use of legacy datasets on forest cover, type, wastelands and limited ground truth as inputs for classification and accuracy assessment.
- Develop geodatabase standards to address retrieval and storage of different data inputs and outputs, designing meta data elements relevant to different types of data, automated output production and interactive querying.
- Implement process based QAS to regulate the data flows and outputs as per the standards.

-
- Develop ‘Technical Manual’ to maintain uniformity of work and Implementation Document to monitor the progress.
 - Generate Net Sown Area statistics for different cropping seasons and Integrated LULC map at the end of year
 - Broad outlines of the project approach is given in Fig. 1 and 2.

1.7. USERS PERSPECTIVE

The project outputs would be primarily useful for the following.

- Provides spatial database on net sown area for different seasons facilitating to monitor and assess different cropping systems under rainfed and irrigated conditions.
- Facilitates rapid monitoring of dynamic land covers like surface water, forest, waste lands etc.
- Serves as primary database for regional EIAs, planning and developmental activities, global environmental issues like Biodiversity, climate change, Land cover atmosphere interactions, carbon sinks etc.
- Works as a useful database for different ministries and departments like Agriculture, Rural Development, Environment and Forest, Water Resources, National Bureau of Soil Survey and Land Use Planning, All India Soil and Land Use Survey etc.

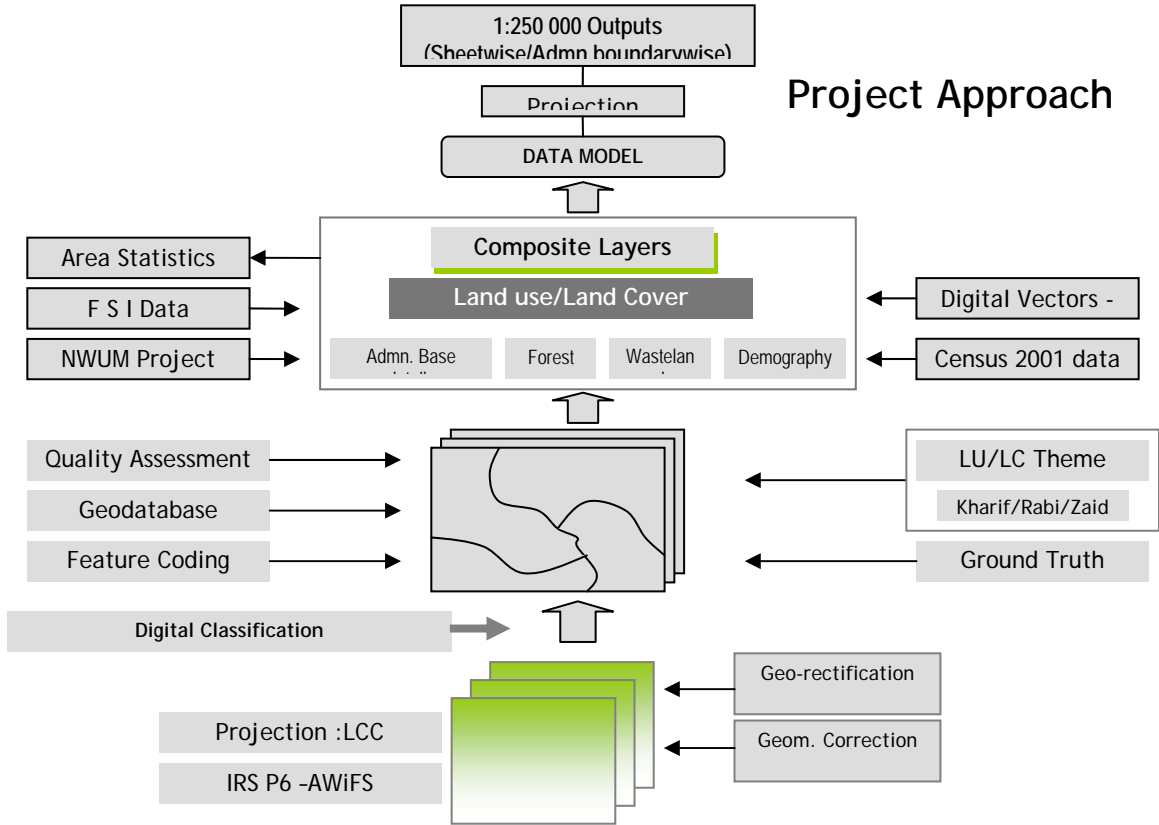


Figure 1. Broad Project Approach

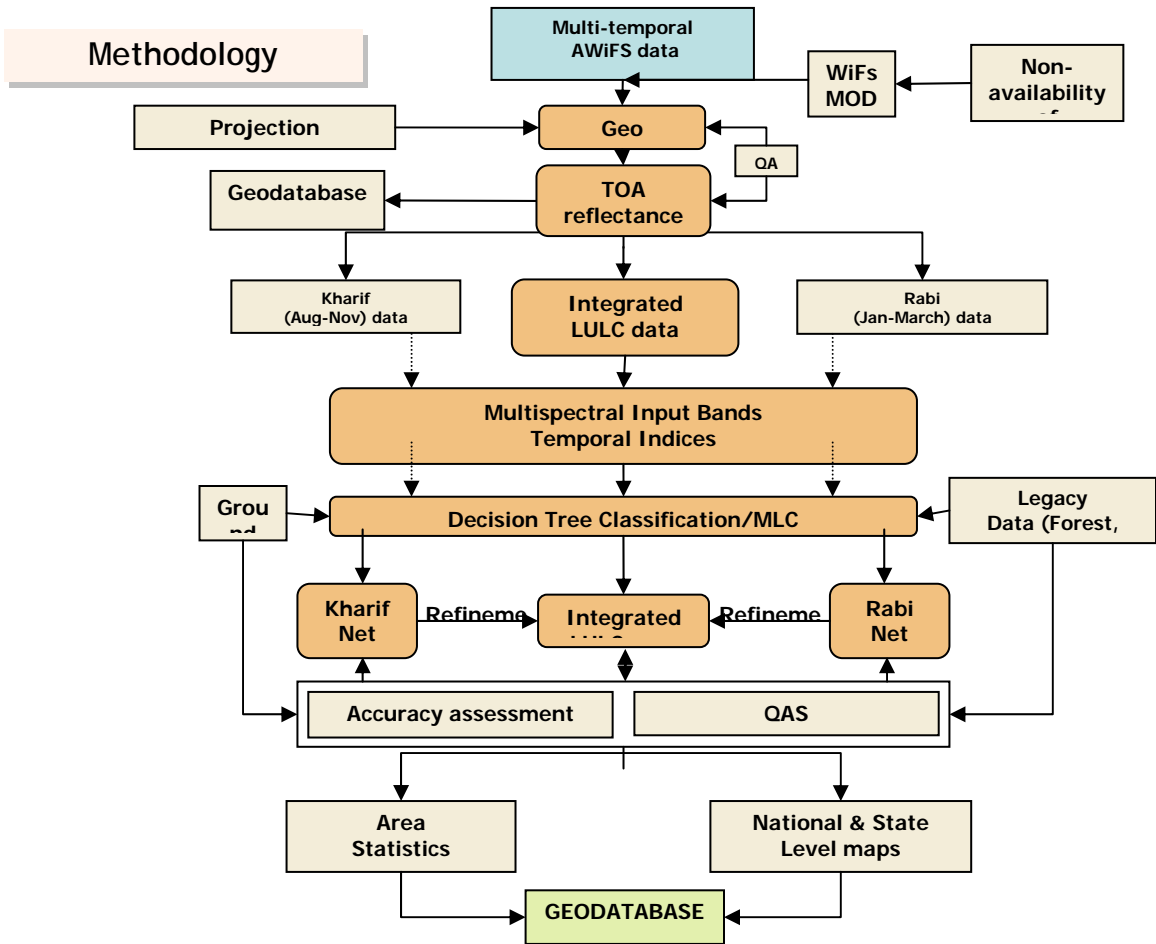


Figure 2. Methodology

CHAPTER -2

GEORECTIFICATION OF SATELLITE DATA

To establish a Natural Resources Repository (NRR), generation of National level assessment of LULC on 1:250,000 scale has been taken up using the Advanced Wide Field Sensor (AWiFS) data of IRS –P6 satellite. NRSA has been identified as the nodal center for Geo-rectification of the input data, maintaining the Geo-database and mapping and classification.

2.1 SATELLITE DATA : AWiFS

IRS AWiFS satellite data is planned to be used mainly, for carrying out the multi temporal classification and mapping. In the event of cloud, alternate data from WiFS, SPOT-VEGETATION, MODIS and NOAA-AVHRR sensors will be used in place of AWiFS. Approximately 80 quadrant scenes are required to be processed to cover entire INDIA. The data requirements are minimum one data set for every month, which will be chosen to address Kharif, Rabi and Zaid crops, forest phenology and to account seasonality of the land cover features.

The AWiFS referencing scheme is based on LISS-III scene center. However, due to the large coverage of the AWiFS scene there is an overlap of 84% between adjacent paths at the equator. Similarly the overlap between adjacent rows is 82%. If the data is chosen in such a way that path P and path P+5 (which is covered on the next day) and similarly row m and m+5 can produce the contiguous area. AWiFS full scenes are defined as four sub scenes called as A, B, C and D quadrants. Each of these sub scene corresponds to the CCD array of 6000 elements of a camera. Each sub scene is of size 374 Km X 372 Km. There is a side lap of 8.4 Km (150 pixels) between A/C and B/D scenes and there is an overlap of 10 Km (150 lines) between A (or B) and C (or D). Some times more number of scenes will be required to cover the cloud free areas. The AWiFS camera operates in 4 spectral bands.

Figure 3 gives the layout of the AWiFS quadrants to cover the whole of India. The whole of India is covered in 21 full scenes of AWiFS. While geo-rectifying the quadrant, care is taken such that the quadrant is lying within the Indian boundary. While rectifying the quadrant with reference to the reference data, ground control points (GCPs) are given in the area covered within India only. Hence while checking the accuracy of the quadrant, only points within the Indian terrain need to be considered. This is clearly entered in the Quality Parameters check form i.e., Form no.5 of Annexure VI.

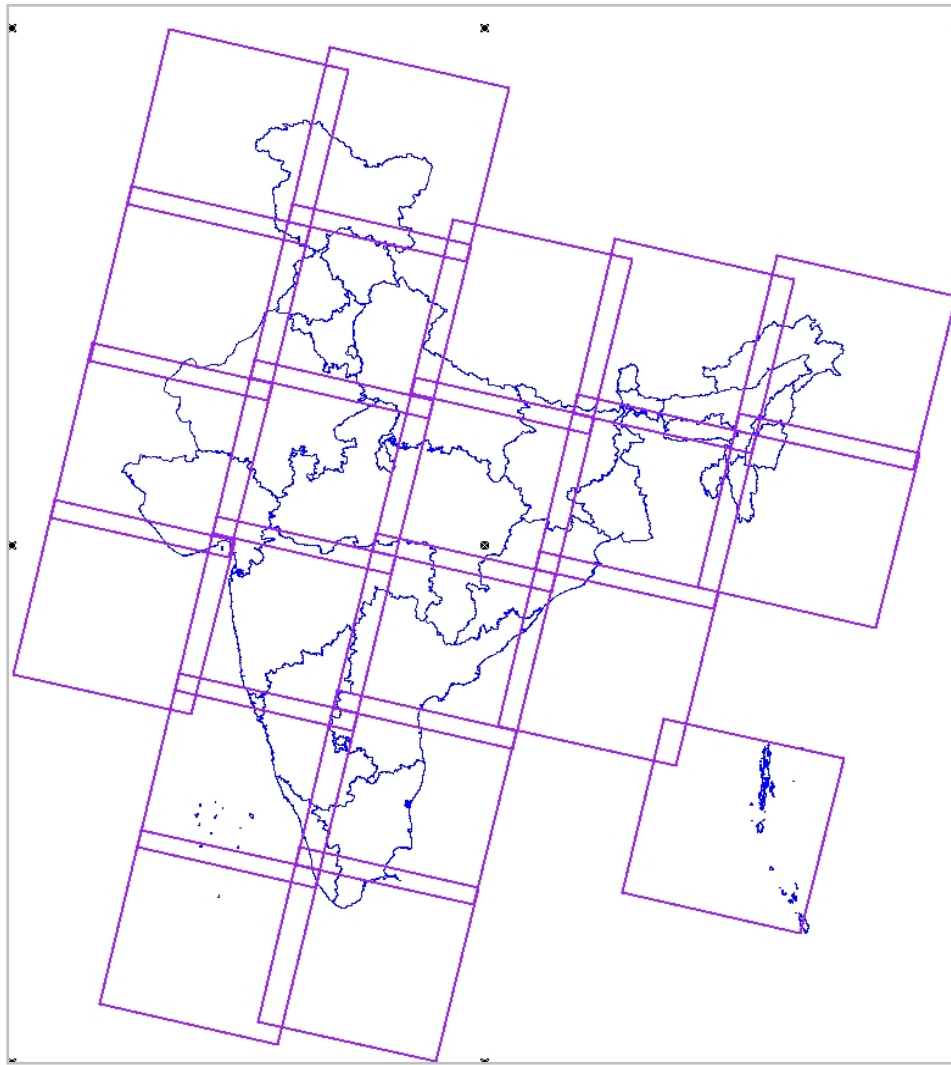


Fig.3 AWiFS scenes layout covering the whole of India

2.2. PRE-PROCESSING OF SATELLITE DATA

Pre-processing of satellite data includes geometric correction, atmospheric correction and radiometric correction.

2.2.1 Geometric correction

The transformation of a remotely sensed image so that it has the scale and projection properties of a given map projection is called geometric correction. A related technique called registration is the fitting of the coordinate system of one image to that of a second image of the same area. Geometric correction of remotely sensed images is required when the image is to be used in one of the following circumstances:

- To transform an image to match a map projection
- To locate points of interest on map and image
- To bring adjacent images into registration
- To overlay temporal sequences of images of the same area, perhaps acquired by different sensors, and
- To overlay images and layers within a GIS.

The main sources of geometric error are:

- Instrument error
- Panoramic distortion
- Earth rotation
- Platform instability

Instrument errors include distortions in the optical system, non-linearity of the scanning mechanism and non-uniform sampling rates. Panoramic distortion is a function of the angular fields of view of the sensor and affects instruments with a wide angular field of view. Earth rotation varies with latitude. The effect of the earth rotation is to skew the image. Platform instabilities include variations in altitude and attitude. All four sources of error contribute unequally to the geometric distortion present in an image.

The process of geometric correction can be considered to include:

- The determination of a relationship between the coordinate system of map and image.
- The establishment of a set of points defining pixel centers in the corrected image that, when considered as a rectangular grid, define an image with the desired cartographic properties, and
- The estimation of pixel values to be associated with those points.

2.2.2 Atmospheric correction

Atmospheric effects on electromagnetic radiation add to or reduce the true ground leaving radiance, and act differentially across the spectrum. If estimates of radiance or reflectance values are successfully recovered from remote measurements then it is necessary to estimate the atmospheric effect and correct for it. Such corrections are particularly important - (a) whenever estimates of ground leaving radiances or reflectance rather than relative values are required, for example in studies of change over time, or (b) where the part of the signal that is of interest is smaller in magnitude than the atmospheric component.

2.2.3 Radiometric correction

If images taken in the optical and infrared bands at different times (multi temporal images) are to be studied then one of the sources of variation that must be taken into account is differences in the angle of the sun. A low sun-angle image gives long shadows, and for this reason might be preferred by geological users because these shadows may bring out subtle variations in topography. A high sun angle will generate a different shadow effect. If the reflecting surface is Lambertian then the magnitude of the radiant flux reaching the sensor will depend on the sun and the viewing angles. For comparative purposes, therefore, a correction of image pixel values for sun elevation angle variations is needed. Such corrections are essential if multi-temporal images are to be compared, for changes in the sensor calibration factors will obscure real changes on the ground.

Standard products accuracy using S band and star sensor is 320m but combination of GPS mode and star sensor method provides 290m location accuracy. For obtaining the precision mapping and temporal observations the data needs to be geo-rectified with high location accuracy. This Geo-rectification part involves the precision geometric correction of AWiFS quadrant scenes with geometrically rectified precision data as reference.

2.3. Projection Standards

A map projection is a device for the representation of the curved surface(that of the earth) on a flat sheet of paper. Many different map projections are in common use. Each projection represents an effort to preserve some property of the mapped area, such as uniform representation of areas or shapes , or preservation of correct bearings. Only one such property can be correctly represented, though several projections attempt to compromise by minimizing distortions in two or more map characteristics.

Two evaluation studies were carried out to finalize the appropriate LCC projection parameters. For this a quadrant covered in Andhra Pradesh and another in Uttar Pradesh were taken.

2.3.1. Study-1

To evaluate the positional accuracy of AWiFS data four quadrants covered in the path-95/row-54 was taken and projected with the standard parallels as well as to the state parallels. The whole of India is taken as one zone with the two standard parallels taken at 1/4th away from the boundary latitudes. The central latitude of the zone is considered as origin. 82° E longitude is considered as central meridian. AWiFS data sets in Geo (Lat/Long) is re-projected to LCC with the above said parallels. Then raw data is geo-rectified using the re-projected AWiFS as reference. Similarly products were generated in UTM and Geo (Lat/Long) projections.

Observations:

- The AWiFS quadrants data with LCC projection and with Geographic coordinate system were compared and the positional accuracy was less than 50m.
- The positional accuracy of the mosaic of the four states was also evaluated and the positional accuracy was found to be within 50m.

2.3.2 Study-2

State wise LCC parameters for the states of Uttar Pradesh and Andhra Pradesh were taken and similarly AWiFS data sets in Geo(Lat/Long) were re-projected. Then the raw data is geo-rectified using this as reference. The first part of the study was designed to study the positional accuracy. A set of GCPL points were compared to the correspondingly identifiable points in the geo-rectified AWiFS data. The positional accuracy was found to be within 100m.

In the second part of the study was the evaluation of radiometry of the products. The raw AWiFS data was classified into 15 classes through digital classification technique (unsupervised). A set of parameters like minimum (DN) value, maximum (DN) value, mean (DN) value, standard deviation and geographical area under each class were computed. The area covered individually for the 15 classes in each projection is calculated and the differences in areas are noted. It is observed that the percentage difference in the areas of the classes is the least in LCC projection. Also the variation in the minimum, maximum, mean, median and standard deviation is also the least in LCC projection. The percentage difference in areas observed between the raw data and the data when projected in lcc, utm and geo(Lat/Long) for the areas of UP and AP are as follows:

UP

Raw_lcc	0.2565463
Raw_utm	0.3299303
Raw_geo	4.2144066

AP

Raw_lcc	0.01035
Raw_utm	0.2186
Raw_geo	0.2887

The study drives us to the conclusion that LCC projection has performed better than the other projections like UTM and Geo(Lat/Long).

Also it has been verified that the LCC projection with the latitudinal extents of 8 degrees gives optimum performance with regard to limiting the maximum scale error. (Reference: Geospatial Database Design Standards). The positional accuracy and the classification accuracy are within the standards specified by the NR-Census project.

2.3.3 Parallels for entire India

A study was also done to study the LCC projection with five parallels with latitudinal extent of 8 degrees. This way India is divided into five parallel zones. A study has also been made to study the positional accuracy of these two projections, the report of which is given in Annexure – I. As per the results of the study done, it has been concluded that two parallels and five parallels have almost the same positional accuracy and thus meeting the project standards. Thus the products covered in the month of December, 2004 and later are being generated with LCC projection and one set of parallels. The LCC projection parameters which are to be followed for the coming set of products starting from December, 2004 onwards will have the following LCC parameters :

Projection:	Lcc
Datum :	Wgs84
Standard Parallel 1:	35° 10' 22.096"
Standard Parallel 2:	12° 28' 22.638"
Central Meridian:	80° E
Origin Of Latitude:	24° N
False Easting:	4000000 Metres
False Northing:	4000000 Metres

2.4. Product Specifications

Satellite data will be processed with the following specifications.

Projection	LCC
Datum	WGS 84
Resolution	56 meters
Resampling Method	NN
No. of Bands	4
Format	ERDAS img

2.5. Reference Data Base:

Precision corrected AWiFS data sets are used as reference data base for carrying out the precision correction.

2.5.1 AWiFS Reference Database

AWiFS quadrants covering the whole of India are available in LCC and WGS 84 datum. This is used for precision correction. This database is highly accurate with a location accuracy of 100m.

2.5.2 Sample Reference Data

Figure 4 shows the false color composite of the AWiFS data which is taken as reference. The sample data shown in the figure is a part of the AWiFS scene covered in the path /row 95/54 of quadrant D. It has Geo (Lat/Long) projection with WGS84 datum. Each quadrant covers an area of 370 x 370 km.

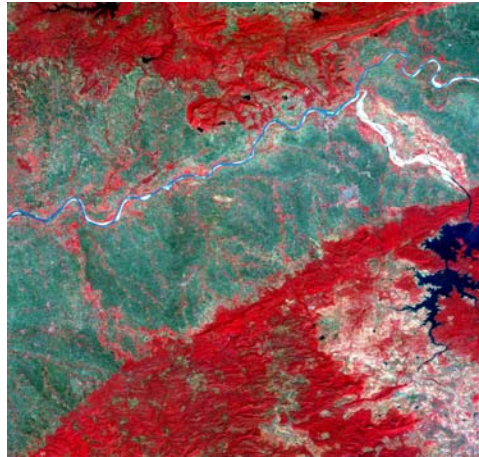


Fig.4 Sample AWiFS reference

2.5.3 Naming Scheme

The data is named according to the path/row nomenclature followed in AWiFS sensor of IRS – P6. Figure 5 gives us the path/row referencing scheme of the AWiFS satellite. The paths are marked on top of the reference scheme in the horizontal direction. Due to large coverage of each AWiFS scene there is an overlap of 84% between the adjacent paths at equator. Similarly the overlap between adjacent rows is 82%. Hence when data pertaining to an area is required, the user should select path P and the next path to be chosen is P+5. Similarly in the latitudinal extent also the next row is selected as (m+5) if m is the row taken into consideration.

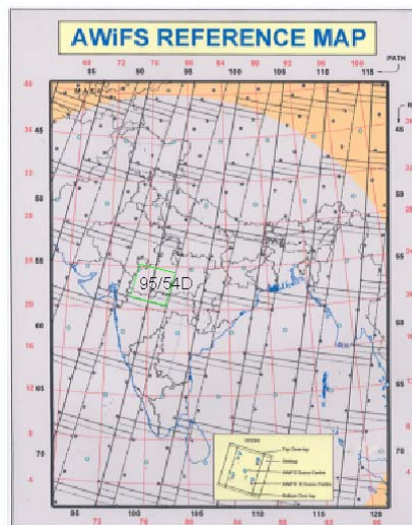


Fig.5 AWiFS reference map

2.6. METHODOLOGY:

The various steps of rectification of AWiFS data quadrants with master reference image is given in Figure 6. and Figure 7.

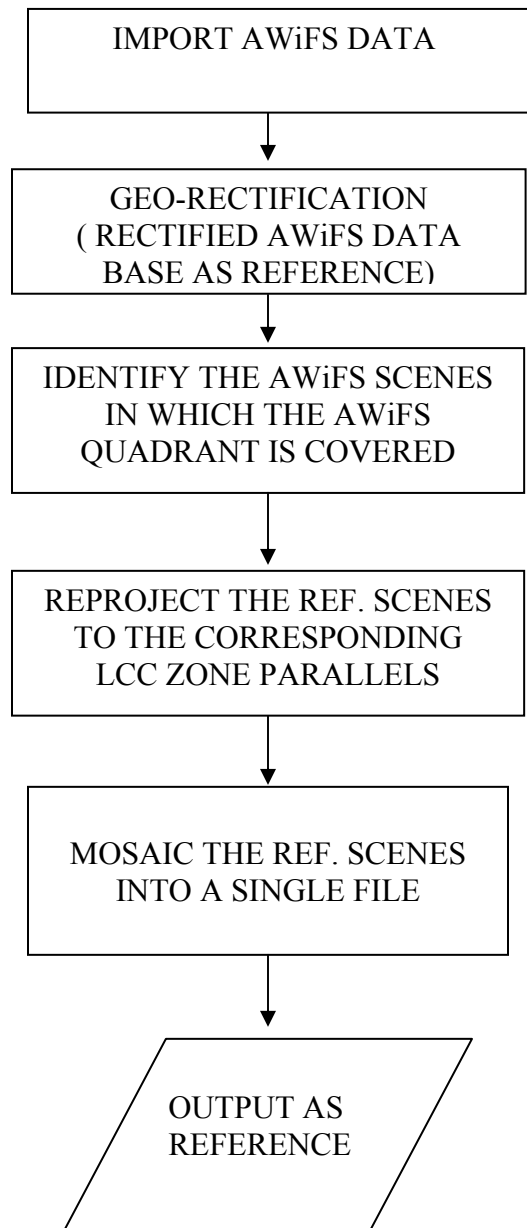
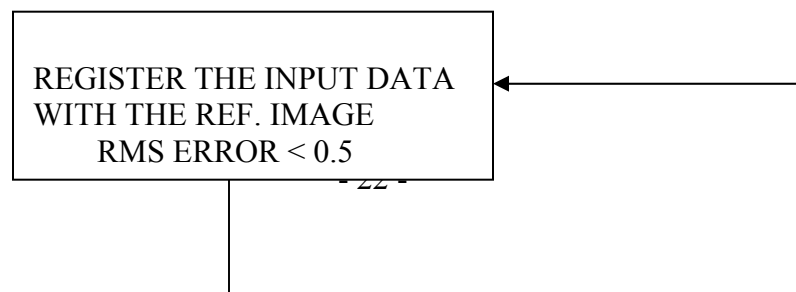


Fig.6 Generation of reference AWiFS data



NO

YES

Fig.7. Flow chart of the generation of the product

2.7. Procedure

- The image processing software used is ERDAS Imagine.
- Import the AWiFS quadrants.
- From the path/row scheme identify the reference scene in which the AWiFS quadrant is covered.
- Identify the LCC parallels in which the required quadrant is covered. Reproject the reference to those set of LCC parallels.
- If registered adjacent quadrants are available, those scenes are also overlaid on the reference scene and registered with the AWiFS scene.
- The GCPs are given in such a way that the RMS error is less than 0.5 pixels.
- For better accuracy and good edge matching between the quadrants, second order polynomial transformation is applied.
- Overlay the resampled AWiFS quadrant on the reference data and check is done by zooming and swiping the scenes. Check is also done by overlaying the adjacent AWiFS scenes too and if the edge-matching is not good, the product is repeated by giving more control points and eliminating the furious points.
- If good registration is observed, quality Form no. 5 of Annexure VI is filled and dispatched to the application scientists.

2.8. Quality Parameters

After the generation of the product and checking the accuracy of the product a QC specified form has to be filled by the geo-rectification team and dispatched to the application scientists along with the product (Annexure VI Form No. 5)

This form includes various parameters to be filled in by the Geo-rectification team. First the NDC request number is entered in the form so that the parameters concerned to the corresponding product is correctly verified. In the fifth row the date of pass and path/row of the quadrant is entered. Suppose if the quadrant falls in the border area, the quadrant is assumed to be covered in a 2x2 grid and the area covered within the Indian quadrant is shown.

In the seventh row the number of GCPs selected for geo-rectifying the quadrant is entered. Here the quadrant is considered to be covered in a 3x3 grid, and hence the number of GCPs covered in each grid is written. After the product is generated it is duly signed by the person responsible for the generation of the product. Also the person (different from the person who has generated the product) who has verified the product signs the form confirming that the product can be queued to the next work center.

CHAPTER – 3

RADIOMETRIC NORMALIZATION OF SATELLITE DATA

Remotely sensed data is affected by the solar incidence angle, solar azimuth, earth-sun distance, viewing angle, atmospheric effects, bidirectional reflectance distribution function (BRDF) of the surface sensed, and sensor band spectral response functions. These factors in combination produce significant band-dependent radiometric differences, confounding the interpretation of both temporal and spatial data sets. When using AWiFS satellite imagery to map LULC or monitor LULC changes, it is desirable to remove these effects by implementing a method which can produce a radiometrically consistent time series of images and mosaics covering large areas. This enables indices or classifications derived for individual satellite scenes to match other scenes both spatially and over time. It enables better use of field measurement sites as signatures in the classification of multiple scenes.

There are a number of physical models for calculating surface reflectance from remotely sensed data; but it is often difficult to get the required inputs at a resolution that is consistent with AWiFS imagery. In this study a hybrid approach will be adopted where the “Top-Of-Atmosphere” (TOA) reflectance will be calculated based on a physical model and the AWiFS sensor calibration factors. The calibration steps (Fig 8) considered in the radiometric correction procedure for AWiFS imagery are - Gain and offset calibration and sun angle and distance correction.

3.1 Gain And Offset Calibration

The gain and offset calibration is applied using the gain and offset data provided for each image band. These values for each image band are obtained from AWiFS sensor report.

3.2. Sun Angle And Distance Correction

The sun zenith angle for each pixel and the distance from the scene centre to the sun are calculated first, then the reflectance correction is calculated for each band. Conversion from calibrated digital numbers (Qcal) in L1 products back to at-sensor radiance (L_λ) requires knowledge of the original rescaling factors. The following equation is used to perform a Qcal –to-radiance conversion for L1 product:

$$L_\lambda = \frac{(L_{Max_\lambda} - L_{Min_\lambda})}{Q_{cal\ max}} Q_{cal} + L_{Min_\lambda}$$

Where,

L_λ = Spectral radiance at the sensor’s aperture in $W/(m^2 \cdot sr \cdot \mu m)$

Q_{cal} = The quantized calibrated pixel value in Digital Number

$Q_{cal\ min}$ = The minimum quantized calibrated pixel value (DN= 0) corresponding to L_{Min_λ}

$Q_{cal\ max}$ = The maximum quantized calibrated pixel value (DN=0) corresponding to L_{Max_λ}

L_{Min_λ} = The Spectral radiance that is scaled to $Q_{cal\ min}$ in $W/(m^2 \cdot sr \cdot \mu m)$

$L_{Max\lambda}$ = The Spectral radiance that is scaled to $Q_{cal\ max}$ in $W/(m^2.sr.\mu m)$

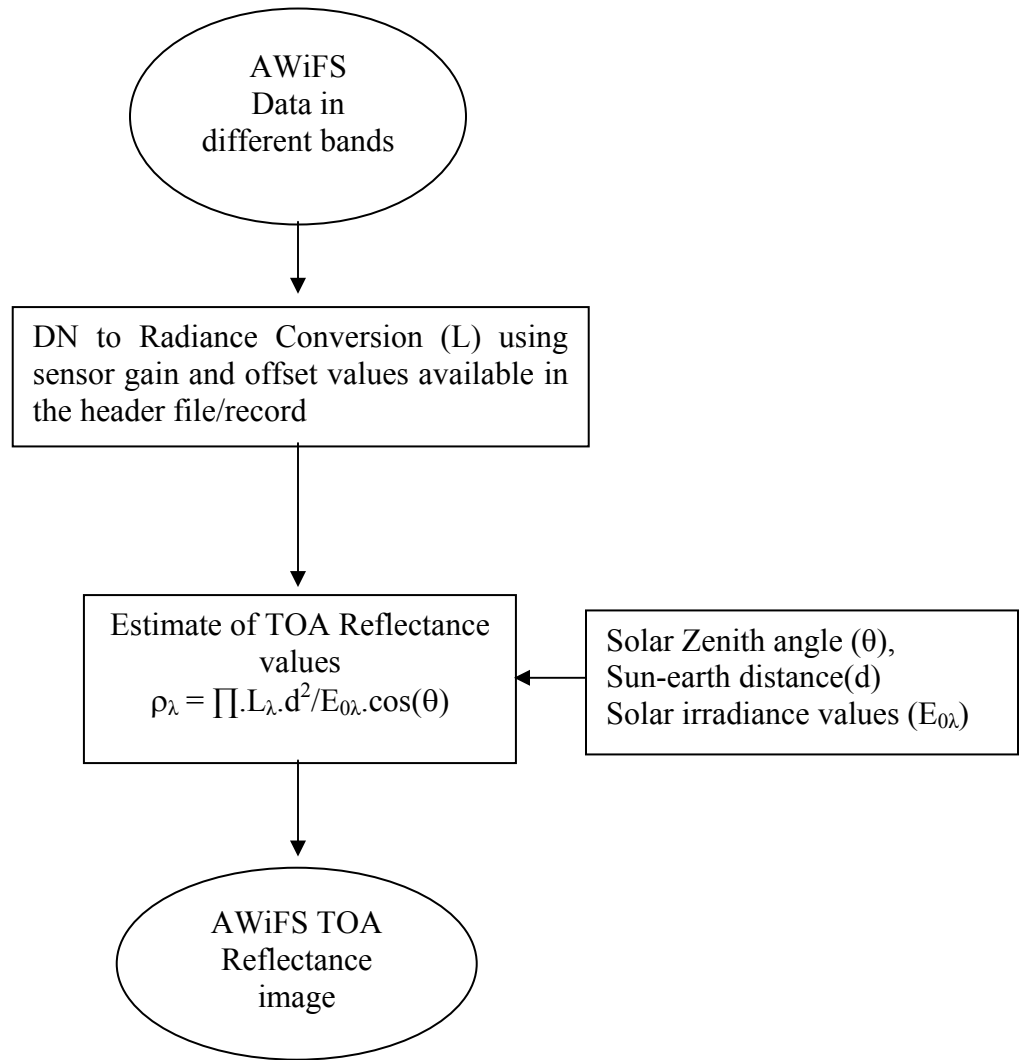


Fig 8 TOA reflectance image generation using AWiFS data sets

Estimating Top of the Atmosphere(TOA) reflectance using IRS-P6 AWiFS data

Conversion formula for Digital Count to radiance is as follows.

$L_{rad} = (DN/MaxGray)*(L_{max} - L_{min}) + L_{min}$.

L_{rad} : Radiance for a given DN value.

DN : Digital Count

MaxGray : 1023 for AWiFS for raw products only.

Lmin/Lmax: Minimum/Maximum radiance value for a given band

Since $L_{min} = 0$ for AWiFS

$L_{rad} = (DN/MaxGray)*L_{max}$

$$= (DN/1023) * L_{max} \text{ (mw/sq. cm / str / micromet)}$$

Example of values taken from AWiFS leader file

Table1 -Values of Lmax and Eo for each band

AWiFS Band	Lmax (mw/sq. cm / str / micromet)	Factor 1 (Lmax/1023)	E _{0λ} (mw/sq. cm / str / micromet)	Elevation Angle(taken from header)	Zenith Angle 'θ' (90-elev.angle)
B1	52.3400	0.051663245	185.47	37.3482972	52.6517
B2	40.7500	0.039833822	155.64		
B3	28.4250	0.027785923	108.24		
B4	4.6450	0.0045405669	23.06		

$$\text{TOA reflectance}(\rho_{\lambda}) = (3.14159 * DN * \text{Factor1} * d^2) / E_{0\lambda} \cdot \cos(\theta)$$

Where

θ = Solar Zenith Angle in degrees

DN = Digital count of respective spectral bands.

Factor1 and E(are to be taken from table-1.

$$d = 1 - 0.01672 * \cos(0.9856 * (\text{day} - 4))$$

While writing the model in ERDAS, simplification can be done based on factors such as E_{0λ}cosθ, (Lmax/1023)for each of AWiFS bands, so that it runs faster. The output of model should be float and the input is AWiFS raw data in unsigned 10bit.

Example: DN = 279 in AWiFS Band1.

Day of pass = January 8, 2005

i.,e. julian day = 8

Solar zenith angle (θ) = 37.3482972 degrees

$$d = 1 - 0.01672 * \cos(0.9856 * (\text{day} - 4))$$

$$= 1 - 0.01672 * \cos(0.9856 * (8 - 4))$$

$$= 1 - 0.01672 * \cos(0.9856 * 4)$$

$$= 1 - 0.01672 * 0.997633$$

$$= 1 - 0.016680423$$

$$= 0.9833195$$

$$d^2 = 0.966917239$$

$$E_0(\cos = 185.47 * \cos(37.3482972) = 185.477 * 0.6066$$

$$= 112.5103482 \text{ mw/sq. cm / str / micromet}$$

DN to radiance

$$L = 279 * \text{factor1}$$

$$= 279 * 0.051663245 = 14.41404536(\text{mw/sq. cm / str / micromet})$$

Therefore,

$$\text{TOA reflectance}(\rho_{\lambda}) = (3.14159 * DN * \text{Factor1} * d^2) / E_{0\lambda} \cdot \cos(\theta)$$

$$= (3.14159 * 14.41404536 * 0.966917239) / 112.5103482$$

$$= 43.7849339 / 112.5103482$$

$$= 0.389163611$$

Multiply the value by 1023 to convert the number to scaled unsigned 10-bit integer reflectance and generate the image i.e., $0.389163611 \times 1023 = 398$

CHAPTER – 4
CLASSIFICATION AND MAPPING

Remote sensing techniques are used on operational basis to map and monitor LULC of a given area at macro and micro level scales. The methodology employed to map LULC consists of both visual and digital analysis of pre-monsoon, monsoon and post-monsoon satellite data, ground truth and other ancillary data. In the present project digital analysis of satellite data for the entire country will be carried out for generating LULC information on 1:250,000 scale.

The current project envisages use of multi-temporal AWiFS data supplemented with WiFS/ MODIS / OCM sensor data, in cloud affected area. In order to bring out uniformity in carrying out the work and in maintaining the high quality outputs, from all the participating teams, procedure to be followed for classification is given in this chapter. Following are the issues discussed:

- Input data - Satellite data, Season of Data, Topographical maps, Legacy Data
- Classification scheme
- Ground truth collection- Sampling design, Size and number of sample sites, Size and number, field work preparation, field equipment, data collection process,
- Analysis of satellite data-Classification of multi-temporal data, single-sensor / multi-sensor data
- Accuracy assessment
- Quality check

4.1 Input Data

Input data consists of satellite data, topographical maps and legacy data.

Satellite data : IRS-P6 AWiFS data geometrically corrected and converted to TOA Reflectance values will form the basic data. The data quality will be evaluated as per Form 6 of Annexure VI.

Season of Data: In this project, multi-temporal satellite data of Kharif (August – October), Rabi (January – March) and Summer (April – May) will be used. Keeping in view the heterogeneity of crop calender over the entire country even within a season, multi-date satellite data use is considered. As an example the heterogeneity of crop calendar in AP state is shown in Fig. 9.

Table 2 Satellite data for different seasons

Sl No.	Season	Period of satellite data
1	Kharif (Monsoon season)	August to October
2	Rabi (Winter Season)	January to March
3	Zaid (Summer season)	April to May

Topographical maps : Survey of India (SOI) topographical maps at 1:250,000 scale will be used for identification of features like roads, settlements, rivers etc., on satellite data. They are also used during ground truth collection. Digital administrative masks from SOI will be procured and used to generate area statistics and final outputs.

Legacy Data : Available Legacy data for themes like forest, wastelands etc., generated using satellite data will be used as reference masks during classification of data.

Data Preparation

The input satellite data should be quality checked as per the data evaluation format and prepare necessary data inputs before proceeding for classification process. Steps to be adopted in this stage are:

- Receive geometrically rectified quadrant-wise IRS-P6 AWiFS data.
- Check the data as per the quality standards (Form 6 Annexure VI).
- If quality is not as per the standards, send it back for re-processing.
- If data is OK, generate TOA reflectance (Use TOA programme supplied) for each quadrant as per the procedure given in Chapter -3.
- Prepare on fly mosaic of the 'state' and assess for data gaps.
- Choose the quadrant covering the major part of the state for a given month and supplement the remaining area with data from other quadrants of the same sensor.
- Mosaic the quadrants (Data of same sensor of the same path) or adjacent path if they are close by dates and having radiometry and seasonal uniformity. The difference between dates of acquisition should be less than 20 days and should not stagger over two crop seasons. Care should be taken that vegetation spectral response exists in the scene for a given crop season (Kharif, rabi or zaid).
- Generate datasets based on the above procedure for all the required months of a cropping season depending on cloud free data availability.
- Prior to classification ensure that 5 km buffer around the state boundary is retained to facilitate border matching of classified outputs.
- Identify cloud-free cropped areas, cloud infested areas, harvested agriculture fields over the selected AWiFS data. Supplement the cloud infested areas and harvested agriculture fields with AWiFS/WiFS/ MODIS/OCM in priority.
- Generate cloud and cloud-shadow masks and harvested agriculture areas masks. Treat these categories of data sets independently for classification.

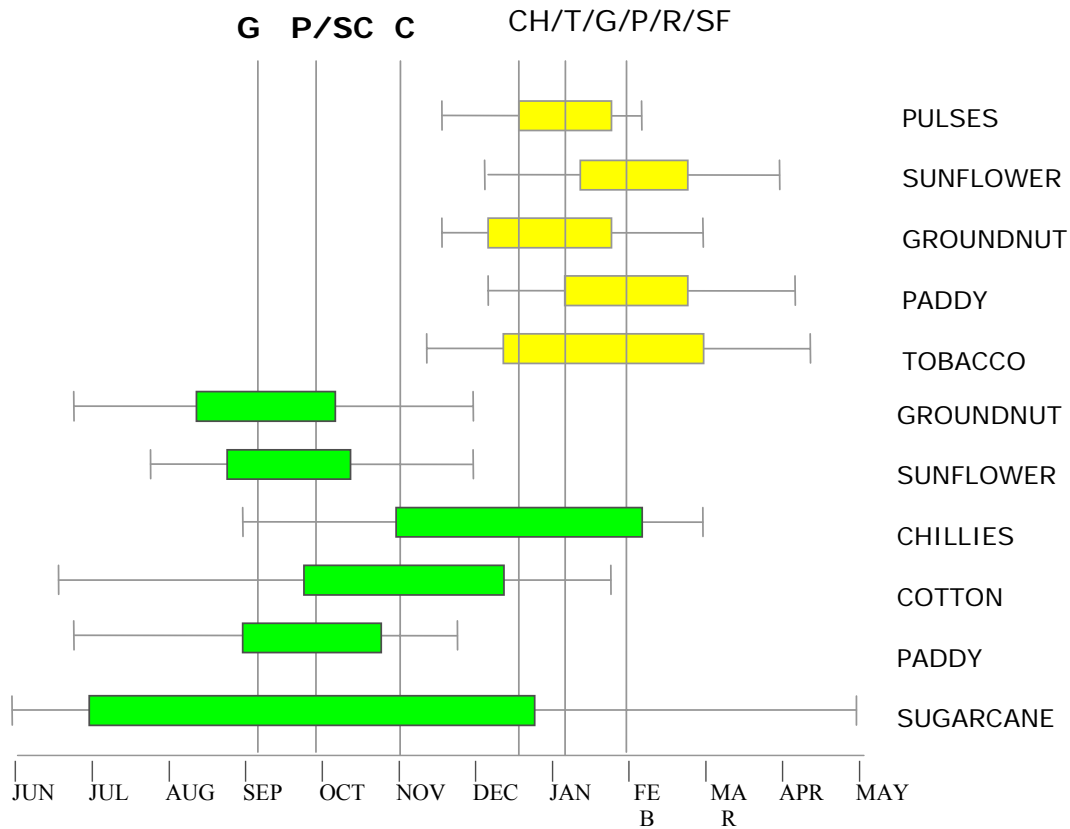


Fig 9 Example Crop calendar of important kharif / rabi crops (Andhra Pradesh)

4.2 Mapping Legend

Mapping legend of the current project is presented in Table 3, which consist of 19 LULC classes. It also shows codes (NRR Standard) and mapping symbology to be used in the project.

4.3 Ground Truth Collection

It forms a very important step in the execution of a project. Ground data is used both for classification and in the subsequent accuracy assessment of the classified image. Many researchers (e.g. Hord and Brooner 1976, Hay 1979, Justice and Townshend 1981, Curran and Williamson 1985, 1986, Congalton 1991, Zhou and Pilesjö 1996) have emphasised the need for use of proper method for collecting ground data and pointed out that the use of inappropriate method may result in “ground lies”.

In most of the projects, the ground data is collected in a single trip, which is made of two parts. The first part of the collected ground data makes up the training data set, whereas the other part is used for accuracy assessment of the classified image. To ensure that the ground data is representative for the spatial population, a suitable sample design has to be chosen. Curran and Williamson (1985) emphasized the importance of the representation

of ground data, both at the scale of the image to ensure an adequate range of data for accuracy testing, and at the scale of the pixel to ensure spatial compatibility between ground data and pixel resolution. The sample design is a critical part of the image classification accuracy assessment. Designing a poor sampling scheme can easily result in significant biases being introduced into the error matrix, which will then affect the classification accuracy (e.g. Richard 1993, Congalton 1991, Lunetta et. al. 1991).

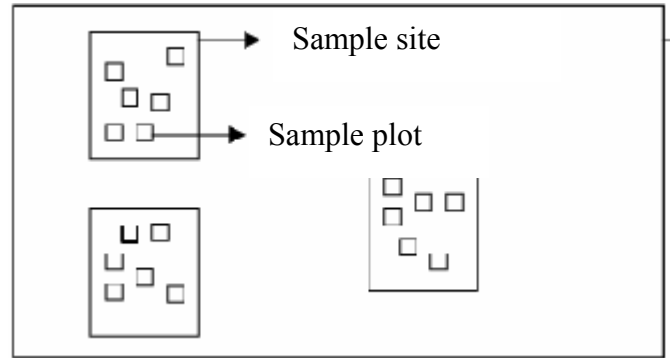


Fig.10 Sampling Frame work

Spatial distribution of sample sites within a study area - The choice of sample sites distribution vary greatly from a simple random sampling to stratified systematic sampling. After performing sampling simulations on spatially diverse areas, Congalton (1988a) came to the conclusion that simple random and stratified random sampling provided satisfactory results. But, simple random sampling tends to undersample small, but possibly important, areas. Therefore stratified random sampling, where a minimum number of samples are selected from each stratum, provide a better choice, according to Congalton (1988a).

Number of sample sites in a study area - The number of sample sites required to characterize study area has been extensively discussed by several authors (e.g. Curran and Williamson, 1985, 1986, Hatfield et al. 1985, Hay 1979, Van Genderen et al. 1978, Ginevan 1979, Hord and Brooner 1976, Thomas and Allcock, 1984). Curran and Williamson (1985) indicated that the number of sample sites within a study area is dependent upon the size of the training data set and the number of classes in the final analysis. They concluded that sample size larger than 30 should be collected in remote sensing studies if sampling errors are to be kept low. Hay (1979) concludes that any sample of less than 50 samples for each category would be an unsatisfactory guide to true error rates. The scheme of sampling frame work is given in Figure 10.








LEGEND FOR MAPPING LAND USE / LAND COVER	
BUILT UP LAND	
BUILT UP LAND (URBAN / RURAL)	
AGRICULTURE	
KHARIF CROP LAND	
RABI CROP LAND	
ZAID CROP LAND	
DOUBLE CROP LAND (AREA SOWN MORE THAN ONCE)	
CURRENT FALLOW LAND	
PLANTATIONS / ORCHARDS	
FOREST	
EVERGREEN / SEMI-EVERGREEN FOREST	
DECIDUOUS FOREST	
SHURB / DEGRADED / SCRUB FOREST	
LITTORAL SWAMP / MANGROVE / FRESH WATER SWAMP	
GRASSLAND & GRAZING LAND	
WASTELANDS	
OTHER WASTELANDS: SALT AFFECTED LAND/SANDY AREA / MINE DUMPS/INDUSTRIAL WASTE/DUMPS/BARREN ROCK / STONY WASTE/SHEET ROCK	
GULLIED / RAVINES	
LAND WITH SHRUB / SCRUB	
LAND WITHOUT SHRUB / SCRUB	
SHIFTING CULTIVATION AREAS	
OTHERS	
SNOW COVERED / GLACIAL AREA	
WATER BODIES	
SHADOW / CLOUD	

TABLE 3 - LEGEND FOR LAND USE / LAND COVER CLASSIFICATION

Size of each sample site - Justice and Townshend (1981) provided a formula to calculate the size of each sample site, in relation to the pixel size and the geometric accuracy of the imagery

$$A=(P(1+2G))^2$$

where: A = area to be sampled

P = pixel size

G = geometric accuracy of the image (in number of pixels)

Hence in the present project where AWiFS data is being used, the area to be sampled may be:

$$A = (56 * (1+2*1.0))^2$$

= 28,224 m² or 2.8 ha: if registration accuracy is about 1 pixel; and it is

= 12,554 m² or 1.25 ha: if registration accuracy is about 0.5 pixel.

For all practical purpose 2.8ha should be considered as the size of sample site.

Number of subplots within one sample site

The number of subplots per sample site is mainly dependent upon the area to be sampled and its spatial variability. In order to determine the spatial variability of a sample site, the standard deviation of a number of spatially random measurements may be used to calculate the relationship between accuracy and number of samples (Rao and Ulaby 1977). The required degree of accuracy ($\pm a$) should be set according to the study, quality of the remotely sensed data, etc. (Fig. 11)

$$N_s = (s_{\square} / t/a)^2$$

where: N_s = number of subplots,

s_□ = standard deviation of measured values

t = tabulated student's t (n-1) ,

a = required degree of accuracy in units from true population mean.

Size of subplots within one sample site

The size of the subplot should be chosen according to the nature of the studied parameter and the applied sampling technique. If the studied parameter is highly variable, the subplot could be made smaller and then a larger number will be required. If, however, the parameter is more homogeneous fewer but larger subplots will be more efficient. The applied sampling technique may decide the size of the subplot.

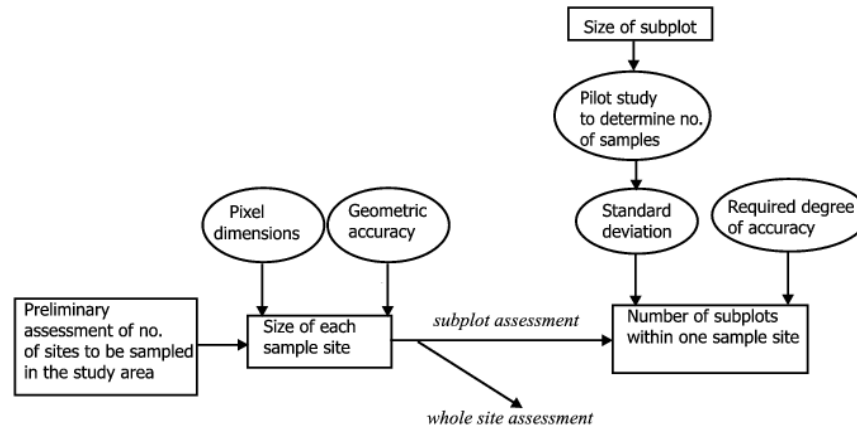


Fig 11 Field sampling scheme

Thus, in the present project the sampling scheme that will be followed for collection ground data is summarized as follows:

- IRS AWiFS quadrant is the unit for classification, ground verification and accuracy assessment.
- Stratified random sampling scheme is suggested.
- Number of samples within each category of interest ought to be at least 30 assuming that no prior probabilities are available.
- Confidence intervals for the accuracy assessment should be presented along with error matrices.
- The area of each sample site should be 2.8 ha size
- When using a subplot assessment, a pilot study should be used to give the number of plots to be sampled in order to achieve a given accuracy.
- Size of the subplot should be based on the heterogeneity of the studied parameter and the applied sampling technique
- Forest and wasteland legacy layers should be used for training set selection and accuracy checking.
- Ground truth efforts should be largely focused on marginal agriculture land, afforested lands, plantation / orchards, scrubs etc.

Field Work Preparation

The objective of sample stratification was to collect an adequate number of field samples in proportion to the spatial variability within a sampling area. One of the primary tools used for sample stratification was the satellite imagery of the area and general physiography / topography of the area. In some mapping zones where topographic relief was extremely variable, the dataset can be combined with other relevant data sources such as elevation data, Normalized Difference Vegetation Index (NDVI) image etc. Initially an automated clustering approach could be attempted to stratify the study area and may be labeled appropriately based on what so ever the *apriori* information available either from topomaps, published maps or existing land use / cover maps.

The clustered image may be clumped to derive the size of contiguous patches under each land use class. Then the clumped image should be sieved keeping the threshold of the size of sample size as defined earlier. Subsequently these clumps along with the road network information may be used to select the sample sites through stratified random sampling approach.

For distributing in the field randomly, a random number generator may be used or the random location generator as provided in ERDAS Imagine may be used on the sieved image. These random points need to be checked for their accessibility by overlaying the road map onto the sieved image. The points, which are not accessible, may be removed and new points be generated. This process has to be continued till the optimum number of sample sites is obtained. Due to practical reasons it may not be possible to visit all the pre-defined points. Hence 10% leverage has to be allowed, on an average. Thus it is advocated to plan for collecting 10% more samples than the actual statistical requirement.

Field Equipment

There are many types of equipment, which are needed for data collection and field verification. They are as follows:

- GPS receiver (having a positional accuracy $\frac{1}{4}$ of pixel size under worst PDOP conditions).
- Laptop / palmtop computer loaded with satellite imagery and ancillary vector layers
- Digital camera, flashcard
- Backup camera, film type
- Batteries
- Power converter / charger
- Hard copy road maps
- Field forms
- Compass
- Binoculars

Data Collection Process

The field data collection has to be planned and work needs to be effectively distributed among the field crew. To begin with the positioning of field crew stations and area of operation (AOP) of each team need to be finalized. Assuming that all the teams will be working for the same time, the points need to distributed as per the criteria discussed above.

Training sites are to be selected based on the homogeneity of the area with respect to: i) the dominant (i.e. diagnostic) cover and ii) abiotic characteristics including the landscape position, elevation, slope, aspect, and soil type, of the site. Sites are to be located on an opportunistic basis while traveling through new areas of a mapping zone. Before starting

the process of recording of GPS observations for knowing geographic coordinates of a site, consideration of following points is essential.

- Whether almanac has been collected (if the position of previous almanac is more than 300km, a fresh almanac needs to be collected, which has an acceptable PDOP and GDOP).
- Whether the datum of the georectified data and that of GPS unit are same?
- Whether the time of signal integration on GPS unit is satisfactory?

Recording of the accurate geographic position of each training site is essential for classification and subsequent mapping. To improve the accuracy, the field crew should record atleast two GPS observation in each site. Immediately after collecting the geo-coordinate, transfer the information on to a vector coverage with appropriate field identification number. On properly orienting the satellite image, locate the site and mark it on the image. Then carefully relate the image characteristics with the site conditions and field properties vis-à-vis its neighbors. Each training site has to be marked by drawing a circle around the site. information on site conditions should be recorded in the ground truth proforma, which could be recorded as attribute information subsequently after reaching the base station. The field information thus recorded should be achieved properly so that it may prove helpful in future studies of monitoring land use/cover change over a longer period. It has been proposed to store the ground truth information in a standardized data base with all the fields as provided in the ground truth proforma as attributes. (Anexure.II) The ground truth points have to be recoded as point vector layer that could be easily linked to the ground truth database through a common attribute.

Training Site Characterization

Biotic and abiotic characteristics are to be used to characterize each site. The percent canopy cover (assuming a 2- dimensional or bird's eye-view) has to be collected for the most abundant and/or diagnostic plant species for each lifeform (i.e. tree, shrub, scrub, grass) using ocular estimates. The vegetation component combined with the percentage of bare ground, litter, surface and exposed bedrock and water, provide an estimate of total land cover. Elevation and UTM position can be collected using a GPS. Slope has to be measured using ocular estimates. Other physical characteristics to be recorded include-landform, aspect, hydrologic class etc. Typically, two digital photographs are to be taken at each site: one from a distance and other in close-up to capture / better show the vegetation and abiotic components at the site.

For each training site, a level of confidence in characterization of the site has to be recorded. The highest level of confidence is obtained when the examiner has the opportunity to “walk through” the training site enabling a positive identification of the canopy cover. Walking through each site, however, can be time consuming. A more rapid site characterization or “quick site” can be used when the examiner is familiar with the area, the dominant species could readily be observed from a short distance and an ancillary data (i.e., landform, elevation, slope, etc.) provide adequate information for labeling the site classification.

The sites that are inaccessible, are referred to as remote or “off-site” training sites. Such sites can be taken if they are within 1.6 km radius from the observer. The ratio of “quick-sites” to “walk-through” sites should be about 4 to 1. This depends on the field personnel’s familiarity with the area being sampled. Each sample location has to be assigned an appropriate land cover label based on the legend finalised. The process of labeling requires a familiarity with the general area and knowledge of what the “associated” cover might be.

4.4 Analysis Of Satellite Data

The project envisages to provide net sown area statistics at the end of different cropping season and integrated LULC map for each crop calendar. In view of this the following two steps are suggested for classification and mapping.

- Generate crop area statistics (Net sown area) for each cropping season using multitemporal AWiFS satellite data.
- Generate integrated LULC map at the end of each year using all the datasets of the year.

Towards the above, based on the number of available cloud free AWiFS data sets and use of other sensor data following classification approaches would be followed.

- Multitemporal Awifs data : Decision Tree Classification Approaches
- Single Awifs datasets : Decision Tree/ML classification
- Multiple sensor data : Decision Tree/ ML Classification

Multitemporal AWiFS data Classification– Decision Tree Approach

Decision Tree approach is a non-parametric classifier and an example of machine learning algorithm. It involves a recursive partitioning of the feature space, based on a set of rules that are learned by an analysis of the training set. A tree structure is developed where at each branching a specific decision rule is implemented, which may involve one or more combinations of the attribute inputs. A new input vector then "travels" from the root node down through successive branches until it is placed in a specific class.

The thresholds used for each nodal decision are chosen using minimum entropy or minimum error measures. It is based on using the minimum number of bits to describe each decision at a node in the tree based on the frequency of each class at the node. With minimum entropy, the stopping criterion is based on the amount of information gained by a rule (the gain ratio). There are several well-established decision tree classifier implementations e.g. SEE4.5, SEE5 (Quinlan, 1993), CART (Breiman, 1984). Decision trees are not constrained by any lack of knowledge of the class distributions, as they do not try to model them in any way.

A decision tree is composed of a root node, a set of interior nodes, and terminal nodes, called "leaves". The root node and interior nodes, referred to collectively as non-terminal nodes, are linked into decision stages. The terminal nodes represent final classification. The classification process is implemented by a set of rules that determine the path to be followed, starting from the root node and ending at one terminal node, which represents the label for the object being classified. At each non-terminal node, a decision has to be taken about the path to the next node. Fig 12 illustrates a simple decision tree using pixel reflectance as input.

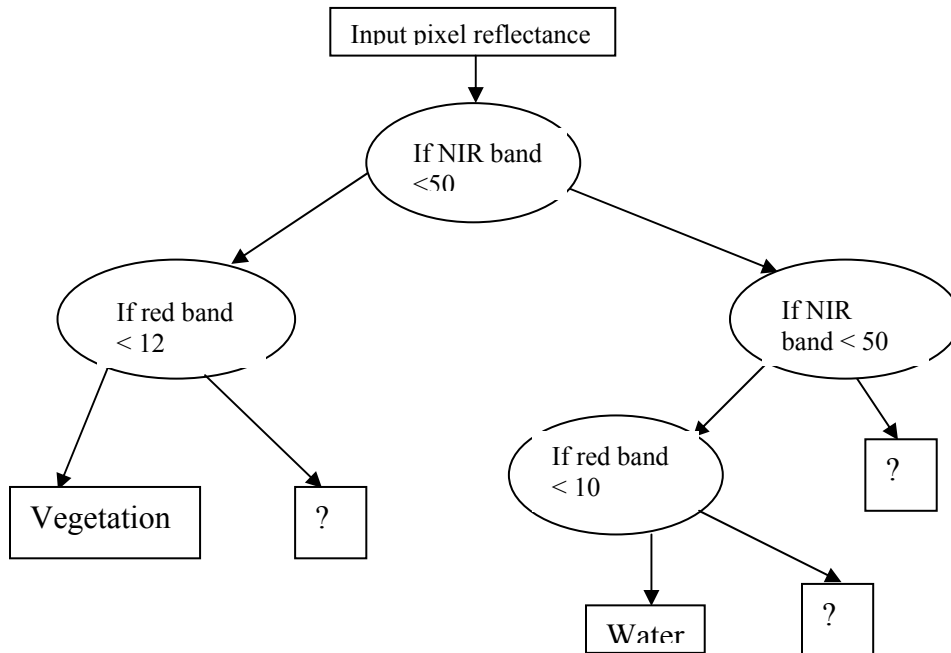


Fig 12 Example of decision tree

The advantages of decision tree classifier over traditional statistical classifier include its simplicity, ability to handle missing and noisy data, and non- parametric nature, Decision trees are not constrained by any lack of knowledge of the class distributions. It can be trained quickly, takes less computational time.

- If there are k classes denoted $\{C_1, C_2, \dots, C_k\}$, and a training set, T , then
- If T contains one or more objects which all belong to a single class C_j , then the decision tree is a leaf identifying class C_j .
- If T contains no objects, the decision tree is a leaf determined from information other than T . If T contains objects that belong to a mixture of classes, then a test is chosen, based on a single attribute, that has one or more mutually exclusive outcomes $\{O_1, O_2, \dots, O_n\}$. T is partitioned into subsets T_1, T_2, \dots, T_n , where T_i contains all the objects in T that have outcome O_i of the chosen test. The same method is applied recursively to each subset of training objects to build the decision tree.

Decision tree classifiers differ in the ways they partition the training sample into subsets and thus form sub-trees. That is, they differ in their criteria for evaluating splits into subsets. The SEE5 or SEE4.5 induction algorithm uses information theory to evaluate splits. CART uses Gini Index to split the training samples (Breiman, 1984) and some methods use Chi-Square measures.

The procedure for classifying satellite imagery with SEE5 decision tree algorithm is described below:

- To begin with, a set of temporal imagery geometrically corrected to sub-pixel accuracy, will form the input data.
- Different channel data of input satellite data sets of a season and NDVI images are used as input.
- Based on a priori knowledge over the study area, a set of points are defined for various land use classes in the data set.
- The scaled reflectance values for land use classes will be extracted for all the ground points.
- All the data will be converted into SEE5 compatible format and has been submitted for extraction of rules.
- Since the boosting option going to change the exact confidence of the rule, the rules were extracted without boosting option. A 10% cutoff has been allowed for pruning the wrong observations.
- Once the rules were framed by the SEE5, these rules were ported into ERDAS Imagine's Knowledge engineer to make a knowledge based classification schema. It should be ensured that 90 % confidence level is maintained for all the classes defined.
- Subsequently the decision tree schema has to be applied over the temporal data set to produce the colour coded land cover output.
- After classification of the datasets Form 7 of Annexure VI has to be filled and should be submitted to QAS team.
- Refine crop classification areas obtained from WiFS/MODIS with AWiFS based classification map at the end of the year.

For single date data analysis even parametric approaches may also be followed if they give satisfactory results.

Data for accuracy assessment

The data for accuracy assessment could be ground data, published maps, available forest type and wasteland maps. Initial efforts should be made to make use of available data banks for accuracy assessment. The ground data collection should be procured for the 'strata' having high variability. A minimum of 30 samples should be taken per class covering the state. However considering the variability and spatial extent of class the number should be appropriately increased.

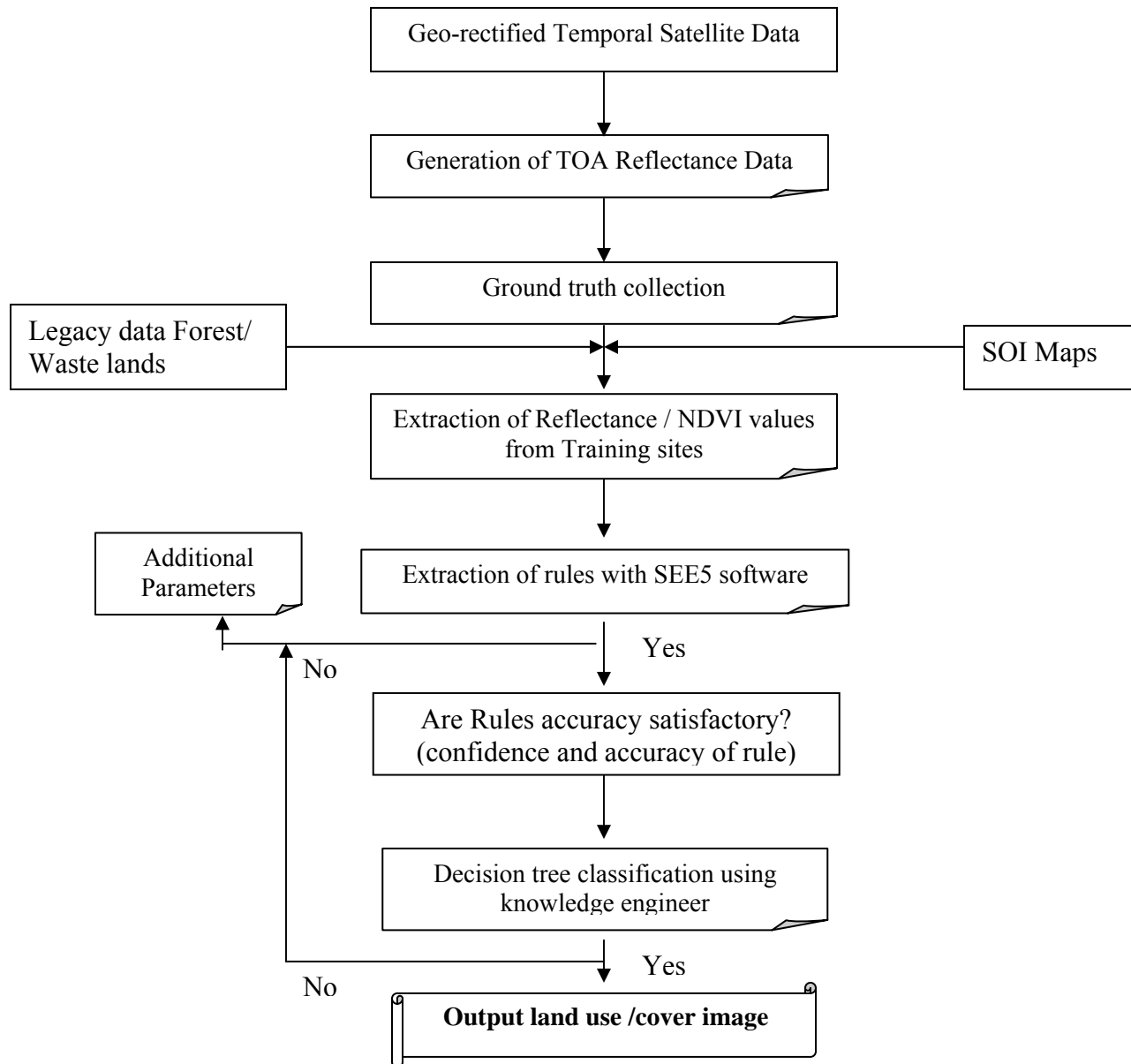


Fig.13 Schematic diagram of the approach for decision tree classification

4.5 Accuracy Assessment

The accuracy estimation is considered to be one of the most important aspects of the study to assess reliability of the classified map. The quantitative approach is one such method through which the overall classification accuracy can be assessed. it is given by,

$$\text{Overall Classification Accuracy} = \frac{\text{No of points correctly on the classified image}}{\text{No of points checked in the field}} \times 100$$

A stratified random sampling procedure can also be adopted for assessing the overall accuracy. The confusion matrix between populations of pixels to that of its distribution among different classes would give overall classification. Accordingly the commission and omission errors could also be estimated to give percentage accuracy of each class. In addition Kappa accuracy can also be estimated. In this project, overall classification accuracy envisaged is 90 % and subtype classification should have at least 85 % accuracy.

Errors of commission for each class are computed by summing the number of pixels assigned to incorrect categories along with each row and divide this number by total number of true pixels in this category. It occurs by erroneously including a unit belonging to the some other category. Errors of omission are computed by summing the number of pixels assigned to incorrect categories along each column and dividing this number by total number of true pixels in this category. It occurs by erroneously excluding a unit from a category, when it belongs to the same class. The ideal number of points to be tested in the classified map is derived from the formula of binomial probability theory. The number of points (N) selected is determined from the following formula (Jenson, 1986),

$$N = 4pq' / E^2$$

Where, p = Expected percentage accuracy; $q' = 100 - p$, E = Allowable error

To determine the accuracy of individual categories (p) in 95 % confidence limit,

$$p = p' \pm [1.96 \sqrt{p' q' / n}] + 50/n$$

where, p' = Value of true percent correct = c/n

$$q' = 100 - p$$

c = No of points correct

n = No of points sampled

The 95 % one-tailed confidence limit for a binomial distribution is obtained from the following expression,

$$p = p' - [1.645 \sqrt{p' q' / n}] + 50/n$$

where, p = overall accuracy.

Kappa coefficient is a measure of agreement between classification and verification.. It is determined from the error matrix, which not only gives the number of correctly classified units but also the commission and omissions. Kappa statistics is defined as follows.

$$k = (\theta_1 - \theta_2) / (1 - \theta_2)$$

$$\theta_1 = \sum x_{ii} / N, \text{ where } i = 1 \text{ to } r$$

$$\theta_2 = \sum x_i + x_{+i} / N^2, \text{ where } i = 1 \text{ to } r$$

Where, r is the number of rows in the error matrix

x_{ii} is the i th diagonal element

x_i is the marginal total of row i

x_{+i} is the marginal total of column i

N is the total number of observations

Large sample variance of the kappa estimate is given as

$$\text{var}(k) = (\theta_1(1 - \theta_1) / (1 - \theta_2)^2) + 2 (1 - \theta_1) (2 \theta_1 \theta_2 - \theta_3) / (1 - \theta_2)^3 + (1 - \theta_1)^2 (\theta_4 - 4\theta_2^2) / (1 - \theta_2)^4$$

where, $\theta_3 = \sum X_{ii} + X_i / N^2$ and $i = 1$ to r

$$\theta_4 = \sum X_{ij} (X_{j+} + X_{+i})^2 / N^3$$

$$i = 1 \text{ to } r$$

The kappa coefficient of 0.90 means that the classification is 90 % accurate. Kappa coefficient is a coefficient of agreement as a measure of total map accuracy. A measure of overall agreement is computed for each matrix based on the difference between the actual agreement of classification i.e. agreement between the visual classification and reference data as indicated by the diagonal elements of the error matrix and the chance agreement which is indicated by the product of the row and the column marginal elements. If $k = 0$, it indicates obtained agreement equals chance agreement. If $k < 0$, obtained agreement is less than chance agreement. If $k > 0$, agreement is greater than chance agreement.

e.g. $\theta_1 = 0.95, \theta_2 = 0.55, \theta_3 = 1.05, \theta_4 = 1.50$. Hence $k = 0.89, \sigma(k) = 0.029$

There are two types of individual proportional accuracies are involved. When the estimated individual accuracy includes the error of commission, it is called the producers accuracy and when it includes the errors of omission, it is called the users accuracy. Conditional kappa coefficients can be obtained for each category i as follows:

$$k[i] = (N x_{ii} - x_{i+} X x_{+i}) / (N x_{i+} - x_{i+} X x_{+i})$$

$$\sigma(k[i]) = 1/N X [A x(B+C)]$$

where,

$$A = P_i + P_{ii} / P^3_{i+} (1 - P_{+i})^3$$

$$B = (P_{i+} - P_{ii}) X (P_{i+} P_{+i} - P_{ii})$$

$$C = P_{ii} X (1 - P_{i+} - P_{+i} + P_{ii})$$

$$P_{ii} = x_{iii} / N$$

$$P_{i+} = x_{i+} / N$$

$$P_{+i} = x_{+i} / N$$

The Overall Classification Accuracy, individual classification accuracies and Kappa statistic will be estimated for the classified data state-wise / quadrant-wise.

4.6 Quality Check Of Classification

Quadrant-wise / state-wise classified land use / land cover outputs will be evaluated by Principal Scientist (PI) and will complete the QA form 7 Annexure VI before sending the same to QAS.

4.7 Mosaicing And Area Statistics

All classified quadrant outputs should be border matched with respect to uniformity of classes prior to mosaicing. After border matching, the classified data should be mosaiced state wise and the area statistics will be generated.

CHAPTER-5**GEODATABASE**

The LULC Mapping with AWiFS project envisages generation of 1:250,000 scale LULC maps using AWiFS data for the entire country once every year. The project's deliverables represent very valuable information whose relevance and use extends beyond the particular year and feed into the preparation of next year's deliverables by way of employing change detection approaches, which also significantly reduces the turnaround schedules for timely delivery of results. By having easily accessible previous years' data, it is possible to provide users and managers with effective content search and query, pre-defined and on-demand statistics and reports generation, map-based interactivity and rich visualization information for discerning trends in LU/LC changes over time as well as predict future scenarios. With necessary security and access control mechanisms in place, it also facilitates highly functional data sharing, reuse, retrieval and distribution besides serving as one of the data sources for national-level natural resource database nodes.

In order to realize these numerous benefits from multiple years' archival data, judicious organization and management of the voluminous spatial database that steadily grows with each year is very crucial. Recent state-of-the-art technology solutions and emerging trends contribute a great deal in designing and implementing highly functional geodatabases. Designing, planning and implementing geospatial databases encompasses a detailed study of the process flow, interfaces to other project activities, input data sources, essential technology elements, data organization schema, GUI design for user interaction, envisaged output products, access control policies, data sharing / transfer modalities and compatibility with national-level databases like NRR.

The geodatabase creation team's role is more encompassing with a long-term view of the data handled under the project. The team is responsible for identifying the important data sets that need to form part of the geodatabase, designing the necessary hardware and software architectures, establishing the mandatory standards and procedures to be followed, and deploying the developed data services for optimal utilization. Figure 14 shows the overview of geodatabase creation comprising of raster, vector and ancillary data inputs to geodatabase, implementation architecture and data services. The following sections describe the various elements of the LU/LC-AWiFS geodatabase design and implementation.

5.1 Spatial Framework

The essential national requirement is to have a geodatabase repository in the digital environment and also in a specific spatial framework for studies at different levels. In this project it is planned to store data in LCC projection system using WGS84 datum where measurements can be made in projected coordinates i.e., meters. The spatial extent shall be the area of eastern longitudes in between 68° & 98° and the northern latitudes in between 6° & 38° .

The mapping scale defined for the project is 1:250,000 where in each two degree is divided into 4 equal parts, each with $1^0 \times 1^0$. Each part is labeled with alphabets. The alphabets are numbered from top to bottom, from left to right (A to D). EX NH 43 6 D covers an area between 28^0 to 29^0 Northern latitudes and 83^0 to 84^0 .

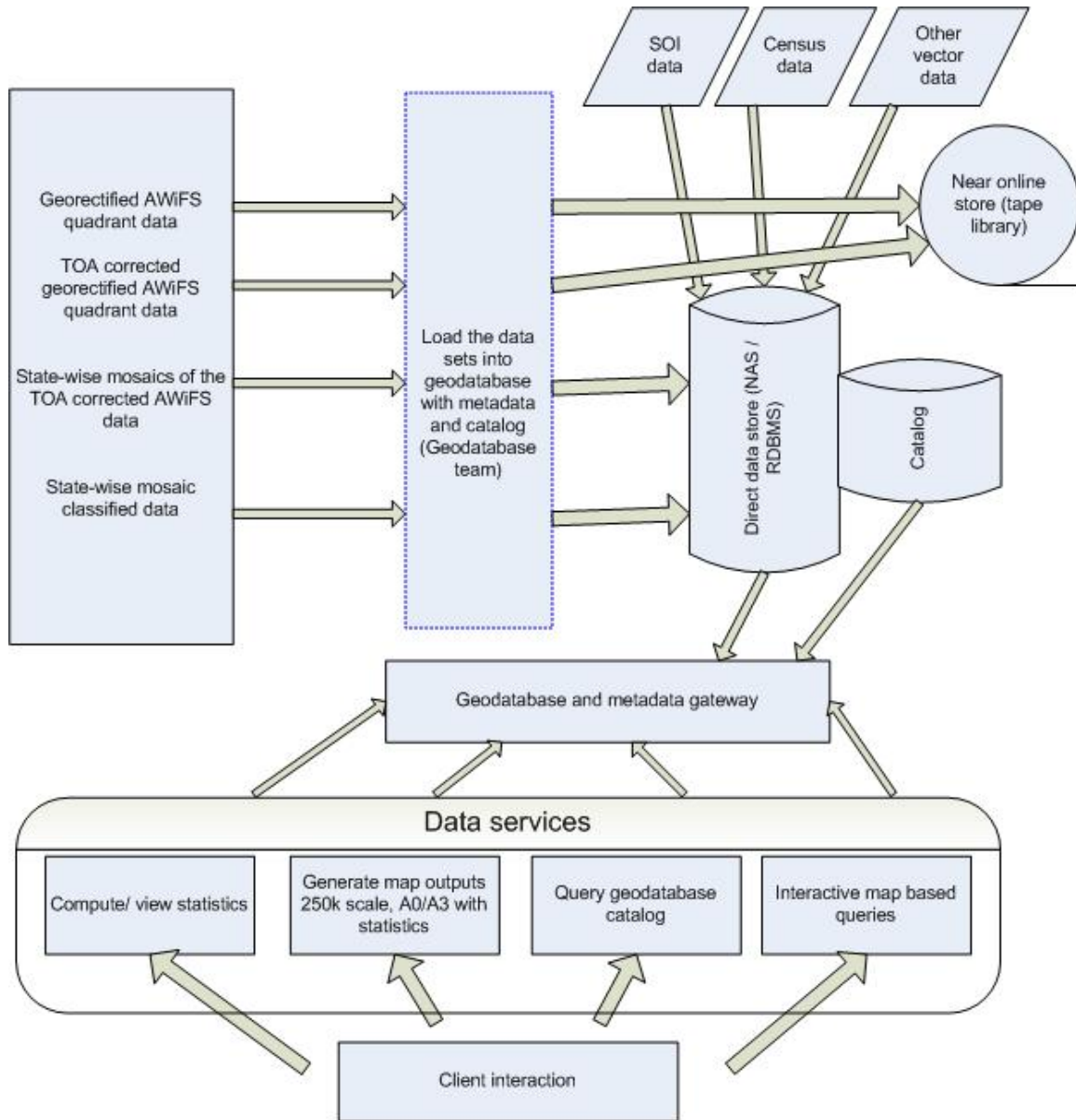


Fig. 14. Overview of geodatabase creation under LULC mapping with AWiFS data

5.2 Data categories and sources

The following data categories are identified as the constituents of the geodatabase under the National LU/LC mapping with AWiFS project and their sources are described in Table 4 and Table 5. All these data sets have relevant associated metadata in XML format. Metadata is discussed in detail in ‘Metadata’ section.

Table 4. Data categories and their source of generation.

Sl.No.	Data category	Category code	Source
1	Georectified AWiFS quadrants	REC	georectification team
2	TOA-corrected georectified AWiFS quadrants	TOA	classification & mapping team
3	State-wise mosaics of TOA corrected georectified data sets	TOA (Mosaic)	classification & mapping team
4	State-wise mosaics of LU/LC-classified data sets	CLS	classification & mapping team

Apart from the above processed and analyzed satellite data sets, there is a need to use primary vector data to derive products like area-specific statistics, administrative unit based analysis and map data services. Census data is another type of data used in the project activities. All these data sets are obtained from different sources and populated in the geodatabase as per Table 5.

Table 5. GIS vector, tabular data and their sources

S.No.	Data Category	Source
1	Administrative boundaries	Survey of India
2	Road network	Survey of India
3	Rail network	Survey of India
4	Settlements	Survey of India
5	Drainage network	Survey of India
6	Census information	Census of India
7	Watershed boundaries	AI SLUS / NRSA
8	Village boundaries	Census of India

5.3 Naming conventions

One of the most important design considerations of a geodatabase is the formulation of a naming scheme for uniquely identifying each data set that is stored in the geodatabase. Towards this, naming conventions are evolved for this project. These conventions are also useful for unambiguous data transfer and sharing among the different processing activities right from georectification of satellite data to final geodatabase creation. The state codes are taken from NRIS standards (Annexure III).

**Geo-rectified AWiFS data :CATEGORY -PATH-ROW-QUAD-DATE.IMG
(Quadrant)**

CATEGORY(RECTIFIED) – REC (3 CHARS)
 PATH – PATH NO. (3 CHARS)
 ROW – ROW NO. (2 CHARS)
 QUAD- QUADRANT (1 CHAR)
 DATE – 141004 (14OCT04) (6 CHARS)

Ex. REC09046A141004.IMG

**TOA reflectance data :CATEGORY -PATH-ROW-QUAD-DATE.IMG
(Quadrant)**

CATEGORY(TOP OF ATMOSPHERE) – TOA (3 CHARS)
 PATH – PATH NO. (3 CHARS)
 ROW – ROW NO. (2 CHARS)
 QUAD- QUADRANT (1 CHAR)
 DATE – 141004 (14OCT04) (6 CHARS)

Ex : TOA09046A141004.IMG

**TOA reflectance data : CATEGORY-STATE-SEASON-CALENDERYEAR.IMG
(State mosaic)**

CATEGORY(TOP OF ATMOSPHERE) – TOA (3 CHARS)
 STATE-NRIS CODE - 0100 (4 CHARS)
 SEASON – KRIF/ RABI/ ZAID/ LULC (4 CHARS)
 KRIF – KHARIF
 LULC – LANDUSE & LANDCOVER (4 CHARS)
 CALENDERYEAR – 0405

Ex : TOA 0100KRIF0405.IMG
 TOA 0100RABI0405.IMG
 TOA 0100ZAID0405.IMG
 TOA 0100LULC0405.IMG

Classified data (State mosaic) : CATEGORY-STATE-SEASON-CALENDERYEAR.IMG

CATEGORY(CLASSIFIED DATA) – CLS (3 CHARS)
STATE –NRIS CODE – 0100 (4 CHARS)
SEASON – KRIF/ RABI/ ZAID/ LULC (4 CHARS)
KRIF – KHARIF
LULC – LANDUSE & LANDCOVER CALENDERYEAR –
0405 (4 CHARS)

Ex : CLS0100KRIF0405.IMG
CLS0100RABI0405.IMG
CLS0100ZAID0405.IMG
CLS0100LULC0405.IMG

Field photos : CATEGORY-STATE-SEASON-CALENDERYEAR-NO.JPG

CATEGORY (FIELDPHOTOS) – FPS (3 CHARS)
STATE-NRIS CODE - 0100 (4 CHARS)
SEASON – KRIF/ RABI/ ZAID (4 CHARS)
KRIF – KHARIF
CALENDERYEAR – 0405 (4 CHARS)
NO – FIELD PHOTO NUMBER
01 – CLASS CODE (2 CHARS)
01 – PHOTO NUMBER (2 CHARS)

Ex : FPS0100KRIF04050101.JPG
FPS0100RABI04050101.JPG
FPS0100ZAID04050101.JPG

Ground Truth : CATEGORY-STATE-SEASON-CALENDERYEAR-NO.DOC

CATEGORY(GROUND TRUTH) – GTR (3 CHARS)
STATE -0100 (2 CHARS)
SEASON – KRIF/ RABI/ ZAID (4 CHARS)
KRIF – KHARIF
CALENDERYEAR – 0405 (4 CHARS)
NO (OBSERVATION Pt. No.) – 01 (2 CHARS)

Ex : GTR0100KRIF040501.DOC
GTR0100RABI040501.DOC
GTR0100ZAID040501.DOC

Administrative boundaries

India polygon: India_country.E00
Ex.: INDIA_COUNTRY.E00

State polygon:	StateCode_STATE.E00 StateCode – Code for the state name (2 chars) as per Annexure III Ex.: AP_STATE.E00
District polygons:	StateCode_DISTRICTS.E00 StateCode – Code for the state name (2 chars) as per Annexure III Ex.: AP_DISTRICT.E00

State polygon represents the main administrative unit for most of the analysis, statistics generation and data services. The constituent administrative units of each state - districts, taluks/ mandals and villages – represent the downward hierarchy. Hence these data sets are prepared and readily kept in the geodatabase as a common source for the analysis and data services. This will minimize the errors that would generally arise if users individually prepare the data sets on their own.

Initially the administrative boundaries are envisaged for use in the project. Subsequently, the other vector layers will be introduced as and when the data is sourced and made available to the project.

5.4. Data capacities

Estimations of data volumes to be stored in the geodatabase and their yearly additions is an important consideration for the geodatabase design. The computation of the data volumes is given below and tabulated in Table 6.

i) Georectified quadrant data

Each AWiFS quadrant 4 bands requires a disk space of 600 MB.

India is covered by 60 AWiFS quadrants.

$$60 * 600 \text{ MB} = 36 \text{ GB}$$

Such data sets will be sourced and analyzed 9 times on an average in a given crop calendar year.

$$9 * 36 \text{ GB} = \mathbf{324 \text{ GB}}$$

ii) TOA corrected georectified quadrant data

TOA data volume is twice the volume of georectified quadrant data since its data type is float (32 bit) instead of 16 bit. i.e 1200 MB per quadrant instead of 600 MB.

$$\text{Total} = \mathbf{648 \text{ GB}}$$

iii) TOA corrected state mosaic data

Number of states taken to be 25 in India and on the average each state is covered by 4 AWiFS quadrants.

$$25 * 4 * 1200 \text{ MB} = 120 \text{ GB}$$

For 3 seasons the data volume will be $3 * 120 \text{ GB} = \mathbf{360 \text{ GB}}$.

- iv) Classified state mosaic data
 Classified data consists of single band; hence the data volume for AWiFS quadrant is 600 MB /4 = 150 MB.
 Considering 25 states and 4 quadrants per state the data volume is
 $25 * 4 * 150 \text{ MB} = 15 \text{ GB}$
 For 3 seasons the data volume will be $3 * 15 \text{ GB} = \mathbf{45 \text{ GB}}$.
- v) Final LULC classified data : Once per year **15 GB**
- vi) Other data
 This includes metadata, statistics, ground truth data and field photographs.
 Estimated data volume will be **30 GB**.
- vii) Vector data
 Vector data consisting of administrative boundaries, transport network, drainage and other cultural features, and census data
 Estimated data volume will be **50 GB**.

Table 6. Data categories and their disk capacity requirements.

Sl. No	Data Category	Frequency of data volume addition	Online/near online storage	volume
1	Georectified quadrant data	yearly	Near online	324 GB
2	TOA corrected georectified quadrant data	yearly	Near online	648 GB
3	TOA corrected state mosaic data	yearly	online	360 GB
4	Classified state mosaic data	yearly	online	45 GB
5	Final LULC classified data	yearly	online	15 GB
6	Other data (including field photographs)	yearly	online	30 GB
7	Vector data	---	online	50 GB

Data categories listed under Sl. No. 1 and 2 are required to be available as easily accessible archives for data downloads and reuse subject to access control policy. These data sets need not be always available online and could reside in near online storage like in a robotic arm driven LTO2 automated tape library. The other data categories

mentioned under Sl. Nos. 3 to 7 are preferably housed online and readily accessible to users via spatial gateway servers. Such data storage mechanism helps for providing data services such as visualization and map based interaction besides on-demand statistics/reports generation.

Vector data is basically less frequently changing data and no significant data volume additions are envisaged. However, the other data category volumes represent yearly generation and addition to the geodatabase. Yearly requirement of disk space for online data categories Sl. Nos. 3 to 6 works out to **450 GB** (360 + 45 +15 + 30).

For the project period of three years, the total online disk space requirement is projected as (Data categories from Sl. Nos. 3 to 7):

$$\text{Total online disk space} = 450 * 3 + 50 = 1400 \text{ GB.}$$

Additionally, common online processing and data sharing/transfer workspace requirement = 200 GB.

$$\text{Grand total online disk space} = 1400 \text{ GB.} + 200 \text{ GB} = 1600 \text{ GB}$$

This requires net 1.6 TB Redundant Array of Independent Disks (RAID) based network storage disk space. In the implementation it is required to provide allowances for RAID parity and hot spare overhead, thus requiring a gross disk capacity provision of at least **2 TB**.

5.5 Compatibility with NRR/ NSDI metadata content

NRR/ NSDI activity has clearly defined a number of data structuring mechanisms for efficient management of geospatial databases by means of standardized metadata content. Since significant efforts have gone into the NSDI database design, it is appropriate to design the LULC –AWiFS database in conformity with that of NRR/ NSDI. This not only helps in leveraging the already defined standards, but also to easily generate NRR/ NSDI compatible outputs from the project database as and when required to contribute, share or transfer data sets to NSDI nodes. Annexure V-A gives the NSDI defined metadata content.

To the extent practically possible, the LULC-AWiFS project metadata content design closely follows the NSDI metadata standard definitions. However, the project aims at providing necessary tools for conversion/ transformation of the project's metadata content to NSDI-compatible formats so as to contribute relevant content to the NSDI network as and when required.

In the NSDI context, NSDI Agency refers to an NSDI node like NRSA, SOI and GSI which maintains the repository. Since the LU/LC - AWiFS project is executed primarily under the aegis of NRSA, the value of 'NRSA' is chosen for this field. Since the details of the project and the work centers do not come under the purview of NSDI, it is essential to define these data structures appropriately. Two examples of data structures that are

independently defined for the geodatabase are: ProjectNames and WorkCenters as described in the following Annexure V-B. More data structures outside the NSDI standard are required to meet project specific needs.

Making use of the NSDILayers metadata definition of NSDI, all envisaged constituent data categories under the LULC-AWiFS project such as georectified data, TOA data, TOA mosaic data, classified mosaic data, classified final LU/LC data and vector data types are described as per the schema. Whenever a data set corresponding to any of these pre-defined layer types (data categories) is added to the geodatabase, a new record is appended to the metadata structure and its elements follow the NSDI defined LayerCat (layer catalogue) schema. This database structure essentially represents the metadata catalog of the geodatabase and is referred to during most search and query operations.

The project uses both framework based and non-framework based processing and hence both layer types are supported in the geodatabase. The AWiFS quadrant based data sets comprising of the georectified and TOA quadrant data are non-framework data and the state mosaics based data sets come under the definition of framework spatial data. The vector grid layers defining the administrative units like states, districts and taluks, and the 250K scale / 1⁰ x 1⁰ grids used for generating map outputs are also framework spatial data.

The NSDI metadata standards complemented by project-related metadata design sufficiently describe the metadata content in a platform-neutral manner. This metadata representation mechanism is distinct from the implementation, export or presentation mechanisms. The metadata implementation can actually take one among many forms. It can also exist in many different forms under different contexts and at different stages of processing or usage. Metadata content is commonly implemented as RDBMS tables, but can also be done as XML documents or in XML-aware databases or sometimes intrinsically embedded within an application package. It is also common practice to routinely and dynamically transform from one form to the other based on need. The various forms of metadata are summarized as given below:

Metadata representation form	:	XML, database schema
Metadata implementation form	:	XML, database tables in RDBMS, embedded in software
Metadata export form	:	XML, CSV, XLS
Metadata presentation form	:	VB GUI forms, Web-based forms, XML+XSLT

Detailed metadata structures designed for the geodatabase of the project are given in metadata section.

5.5.1 Metadata

Geodatabase consists of various categories namely georectified quadrant data, TOA corrected quadrant data, TOA corrected state mosaic data, classified state mosaic data,

and GIS vector data. Data sets in each of these categories will have an associated metadata, which describes the data content, helps in search and retrieval and announces the quality related values. The metadata elements for each of the categories are given in the following Annexure V-D to F.

GIS vector data is basically received from survey of India (SOI) or other agencies. The vector layers are used as reference data for performing GIS operations on the raster data sets populated under the project for extracting area of interest, generating statistics, overlaying cultural features and annotations. Even though metadata is already built into the datasets, additional elements relevant to the project are created under this project for search, query and retrieval of the data sets.

5.6 Geodatabase architecture and organization

The overall geodatabase architecture was presented in Figure 14. Further details of geodatabase organization and implementation mechanism are discussed in this section.

The geodatabase contains data sets of varied nature. As already discussed, some data sets need to be available online as direct-access content, whereas some others could be relegated to a secondary storage to be retrieved when needed. A few data sets may have availability requirements that lie somewhere in between. Based on the availability of infrastructure resources like disk space, in practice, the primary high-available data sets may be moved to secondary storage or vice-versa. These considerations dictate the need to implement a hierarchical storage system for the geodatabase with some location transparency with regard to the user's view of the actual physical location of the data sets in the geodatabase. The hierarchical storage system with possible allocation of data categories to storage types is depicted in the following Figure 15.

The ingestion of content into the geodatabase constitutes one of the important activities of a geodatabase. The different input data categories for the project are shown in Figure 16. Data input process must necessarily include the creation of metadata for each data set that goes into the geodatabase and is explained below.

The metadata creation is simplified by means of a GUI form-based client program. This program generates both an XML format metadata file as well as MS Excel format file. For all data sets to be ingested in to the geodatabase, Form 8 to 13 of Annexure VI are to be filled. The process of data preparation through mandatory keying in of metadata and quality related parameters has to be ensured using the client programs at respective stages before the data is made available for ingest in to the Geodatabase repository.

The data has to necessarily be associated with the metadata in the form an XML file. A sample XML document is given in Annexure IV. Both the data set and the XML file are named in accordance with the defined naming conventions. Sufficient care has been taken while designing the file naming conventions so that the existing files are not overwritten. This facilitates system administration operations for fast query and search operations to be performed on the filename itself without accessing the metadata content each time.

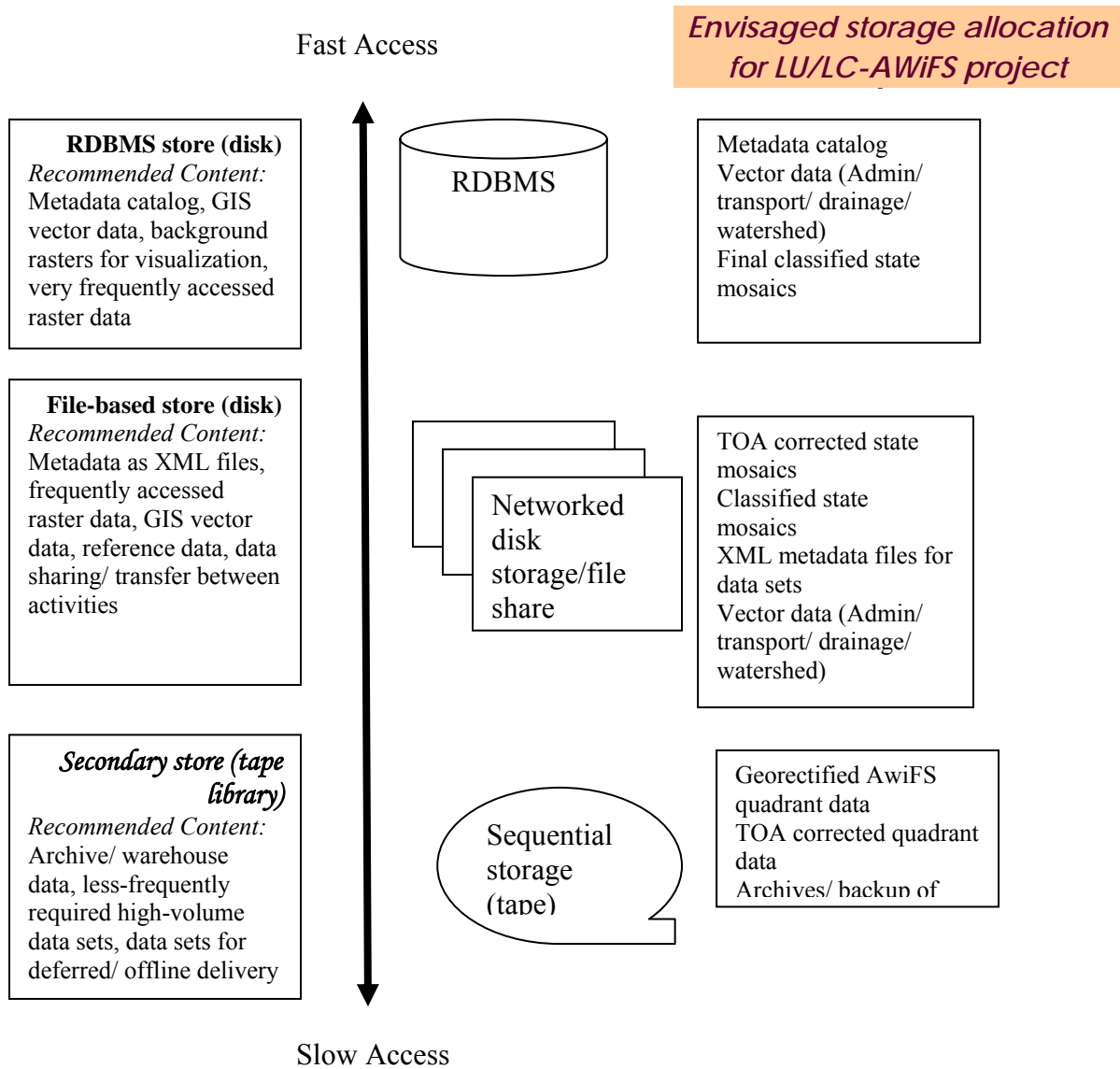


Figure 15. Storage allocation of different data categories

The actual geodatabase ingest process comprises of the following steps (Figure 17):

- Accessing the files comprising the data set on the shared networked storage
- Reading the metadata XML file associated with the received data set
- Checking for its well-formed ness
- Checking whether all the mandatory fields are filled-in
- Checking whether the values are valid (for fixed-domain and constrained elements)

- Populate the metadata catalog in the RDBMS with new record(s) reflecting the availability of the new data set and transfer the metadata information from the XML file into the RDBMS records. The actual data set is not stored in the catalog
- In the process of adding to the metadata catalog, an accession number is generated for the new data set

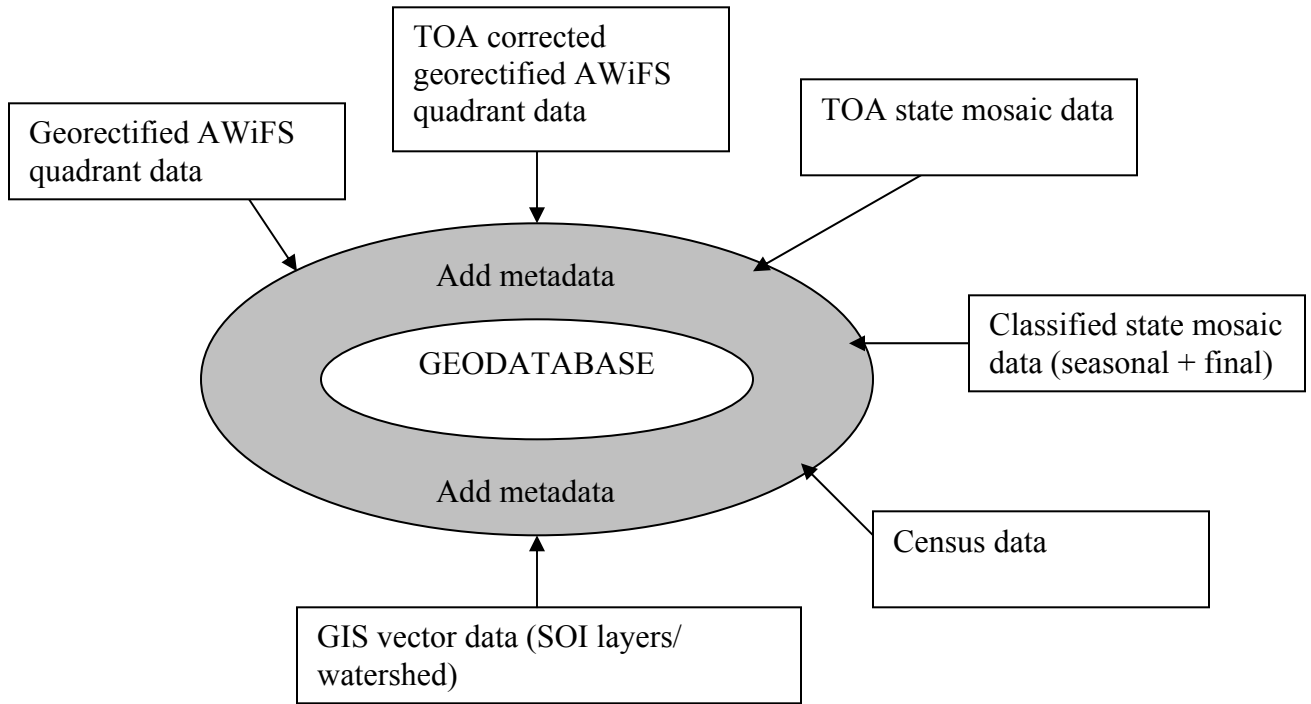


Figure 16. Categories of data sets in geodatabase.

- The actual data set content is now transferred to the appropriate location in an RDBMS/ disk/ tape library based on the level of hierarchy the data category falls into as per pre-defined policies
- The location of the actual content stored in the above step is recorded in a metadata catalog field as an URI (Uniform Resource identifier) for future access

5.7 Security and Access Control

Managing controlled access to sensitive data stored in geodatabases is an important component in an organization’s security policy. This is especially true in the case of RS and GIS spatial data because high-resolution data are highly restricted for reasons of national security. To enforce proper access controls for the data, it is required to associate appropriate access control privileges for each spatial data set. Only authorized users holding sufficient rights appropriate to the defined privileges should be allowed access to the data. Data access privileges and rights are also further differentiated based on the type

of access, namely, browse, view, store, retrieve etc. Such fine-grained access control mechanisms normally require customized programming using suitable technologies.

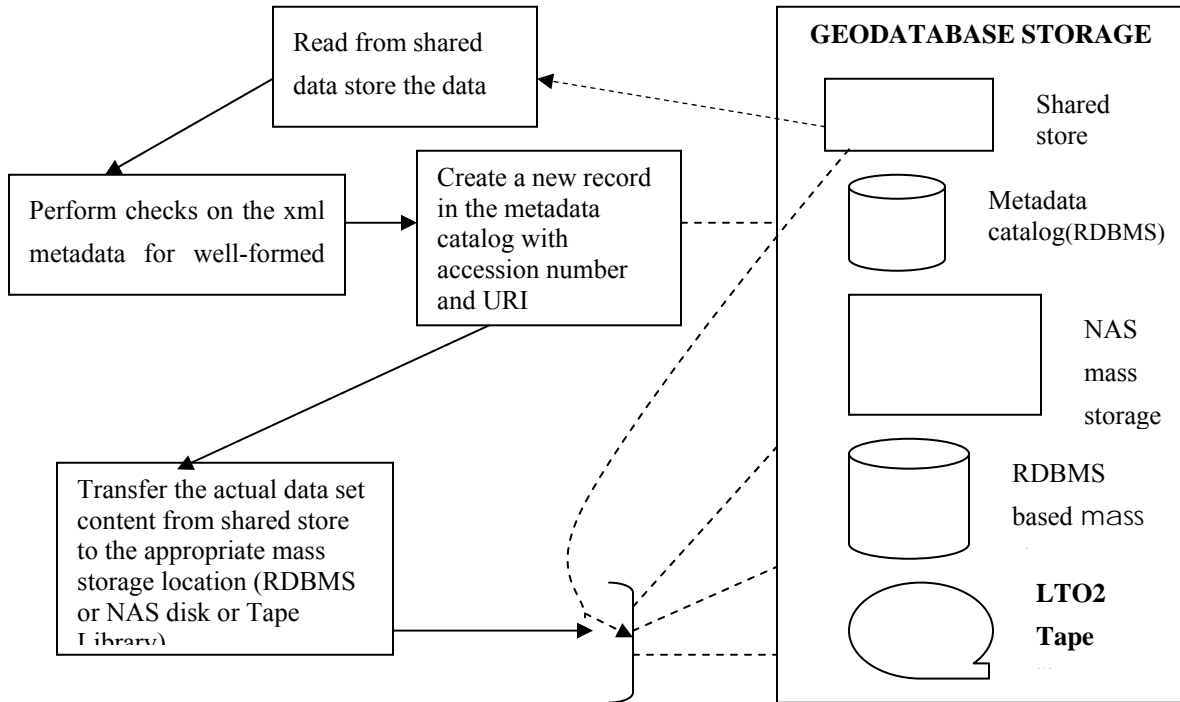


Figure 17. Geodatabase ingest process.

In most GIS server environments, database connections are governed by username and password security mechanism. Commonly used datasets, which are not restricted, can be made available to all users by implementing a set of usernames and passwords corresponding to different groups of users. More comprehensive access control to datasets can be designed by setting appropriate privileges on the dataset itself for the selected usernames and roles. This would suffice when the number of users and their roles are limited. When there is a large number of users each belonging to different privilege groups at different points of time, even this security mechanism is not adequate. Further complexity is introduced when proper authorization is required to access secure datasets in an automated fashion. To model the user interactions and security mechanisms, it is necessary to develop customized server modules leveraging the power of GIS middleware.

The National LU/LC Mapping using AWiFS project execution is carried out by multiple teams at various distributed work centers. Hence it is not possible to apply any one single uniform security mechanism across all activities. Considerations like type of data handled, number of persons, group activities, need for data sharing & transfer and whether connected to network influence the nature of security procedures adopted.

The type of satellite data handled under this project is of 56m resolution AWiFS data and the target scale of mapping is 1:250,000. Since these parameters are rather coarse, the security classification of the data sets can be taken as 'moderate'. Keeping this in view and based on practical considerations, the envisaged security policy for data sets handled under this project does not grant access to anyone not part of this project. But at the same time it is not too restrictive for project members.

Network access to data is essential to facilitate data sharing and transfer among all the members of various teams for accomplishing the specified tasks, implementing the central geodatabase repository and developing applications.

The georectification activity is accomplished in a network which is not physically isolated from the campus LAN and hence ensuring an inherently secure network environment. Further, physical access to the processing systems is restricted only to the team members based on username/ password. The end products of this activity - georectified AWiFS quadrant products – are delivered to the designated on CDs.

Adequate care is taken in updating the systems with necessary security patches and virus protection. The access to the system is by means of username/ password and the data sets are not located on shared folders. The classification, QC and geodatabase activities are primarily restricted to Applications Area Network which is not physically isolated from campus LAN. But it runs on an IP domain that is different from campus LAN. Hence logical isolation for networks is taken care of to ensure sufficient security. Further, IP address and MAC address based screening of network traffic is configured on the networked storage systems to protect from unknown hosts.

The three types of network-based data access are identified under the project. They are

- Teams / members accessing shared storage on NAS
- Download operations on data sets already stored in geodatabase archives
- Clients accessing customized geodatabase applications for map outputs, query & visualization

Members of the classification team extensively use shared storage on NAS for collaborative processing work. Shared storage does not mean that it is freely accessible for any user. An Active Directory server that is in-built in the NAS governs the valid users. Fine-grained access controls based on user/ role/ activity can be configured to provide the requisite amount of access to the users. For the classification team, a group called 'lucls' is created with three usernames – 'clsteam1', 'clsteam2', and 'clsteam3' - corresponding to three classification sub-teams. Three share names – 'lucls1', 'lucls2' and 'lucls3' - are also configured so that only the respective sub-team has full access to the folder while others have only read access. A lot of flexibility and convenience is achieved by having shared folders for sub-teams, because processing work on a data set can be continued seamlessly across persons and shifts. There is also a common shared folder – 'lucmn' - to which the entire group has write access. This folder is used not only to distribute the received input data sets to sub-teams, but also to receive and pass on the

intermediately processed data sets like TOA corrected quadrant data among sub-teams. A similar shared folder is envisaged for passing on the final data sets for geodatabase creation. The NAS shared folders are also configured to screen out invalid content like MS word document and executable files. The usernames, shared folders and access control permissions discussed above are shown in the following Table 7, where 172.27.128.35 represents the IP address of the NAS gateway cluster.

Table 7. Access to NAS infrastructure

SL.NO	USER-ID	PASSWORD	SHARED FOLDER	PERMISSIONS
1	clsteam1	*****	\\172.27.128.35\lucl1	RW to lucl1, lucmn; R only to lucl2 and lucl3.
2	clsteam2	*****	\\172.27.128.35\lucl2	RW to lucl2, lucmn; R only to lucl1 and lucl3.
3	clsteam3	*****	\\172.27.128.35\lucl3	RW to lucl3, lucmn; R only to lucl1 and lucl2.
4	Users logged in using any of the above user accounts can access this common shared folder		\\172.27.128.35\lucmn	All the three users can RW to this folder. Received Geo-rectified data will be loaded to this folder using any of the three user-ids. Other team members can access the respective geo-rectified data for their analysis.

RW- Read Write, R- Read only

Once the data sets are ingested into the geodatabase, they are no longer accessible for free download from shared folders. Prior to storing them in the geodatabase, the metadata of the data sets is populated into the metadata catalog in RDBMS. The catalog is utilized by customized program interfaces to describe the data sets to the user. Once the user is satisfied with the usefulness of the data set, he can request for actual data delivery. At this stage resource-based access control is enforced. Every data set has the authorization level embedded in its metadata. The authorization level represents the designation of the person who can authorize the download. This authorization process can be electronic with the help of custom software or manual. On successful authorization, the data set is available for download or transfer to the user’s shared folder.

A sample XML segment describing the access constraints implementation for this type of network access is shown below.

<constraints>

```

    <access_constraints>
        <query/>
    </access_constraints>
    <use_constraints>
        <retrieval>dd </retrieval>
    </use_constraints>
</constraints>

```

Another method of accessing data across network is in a client-server or 3-tier environment, where an application server/ map server/ middleware application handles all the user requests typically emanating from a thin client like the web browser. In this case, the data is made available only through the middleware so that security is built into the middleware application. The middleware or a directory server manages the usernames/ passwords. Instead of allowing download of entire data sets, this architecture primarily allows different views of the data as governed by user interaction and query. In addition to the resource-based access control, the custom application looks at the user's privileges to determine what actions or services a user is authorized for. For example, a user may be allowed to request for an A4 size map output but not for an A0 map output with statistics.

5.8 Data services, Visualization and Customization

These services are achieved through pre-defined map outputs, custom made map outputs, on-line database search, logical queries, on-line statistics computation, and map based interactive queries.

Catalog query and search: The search process relies extensively on the metadata associated with the data sets. While all elements of the metadata are possible candidates for search, a sub-set of these elements fall under the category of most frequently asked queries. A user interface for search is designed accordingly to capture most of the requirements of the user. The search queries range from simple to complex combination of metadata elements. For example,

Simple queries

- Show all the georectified data sets falling on a particular date.
- Show all the georectified data sets falling in a given path-row.
- Show all the classified data sets for a given state.

Complex queries

- Show all TOA data sets falling under a given set of path-rows and a given period.
- Show all classified data sets belonging to a given state where overall kappa accuracy greater than 85% and less than or equals to 90%.

The information contained in the metadata catalog is by itself not sufficient to provide the required results for some queries. Such queries may require geo processing on the

geodatabase before presenting the results to the user. For this the GIS middleware routes the generated sequence of queries to the spatial gateway server and obtains the processed information before presenting it to the user in web browser environment. This entails significant customized software development. Examples of such queries are:

- Show all districts in a state where population is greater than a given threshold and cropped area is less than a given threshold.
- Show all states where net sown area has increased at least 10% from the previous year.

Normally the above queries will result in producing a list of items matching the search criteria. User will be provided a facility to display the map against each of the listed items through a hyperlink.

Map based query and search: In map based query and search method India map will be displayed initially to query on state, district, watershed or a given area of interest (AOI). The viewer application running on the client system periodically generates appropriate queries based on the user interaction and routes them through the GIS middleware to the spatial gateway server to obtain the processed information before presenting it to the user in the viewer environment.

5.9 Deliverables

The LU/LC seasonal and final classified data sets are the primary sources for generation of statistics and maps. The state/district level maps as well as area statistics can be extracted from the input data sets more easily. The map output comprises of map elements like LU/LC theme map, overlay of base map features, legend, area statistics, index map, location map, agencies involved, sources of data, project name & year of publication, theme title, scale bar and north arrow. A sample of the standard format of map template adopted from NR-Census project for the map outputs is shown in Figure 18.

The envisaged map output products are of the following types:

- Standard 1d x 1d map extent corresponding to SOI 1:250,000 scale indexed toposheet in A0 size.
- Map pertaining to a district in A0 size.
- Map pertaining to a state in A0 size.
- Map pertaining to India in A0 size.
- User defined AOI map extent in A0 size.
- Maps in A3 size corresponding to type 2- 5 above.

Since user interaction for hard copy generation of map outputs is planned to be web based, a set of automatic tools for this process are envisaged for development. This helps in bringing uniformity, convenience and reuse for map generation process. Once the desired map output is displayed on the screen, the user can opt to save the composed map in a pdf format. Towards this customized software is planned for development as a part of the project activity.

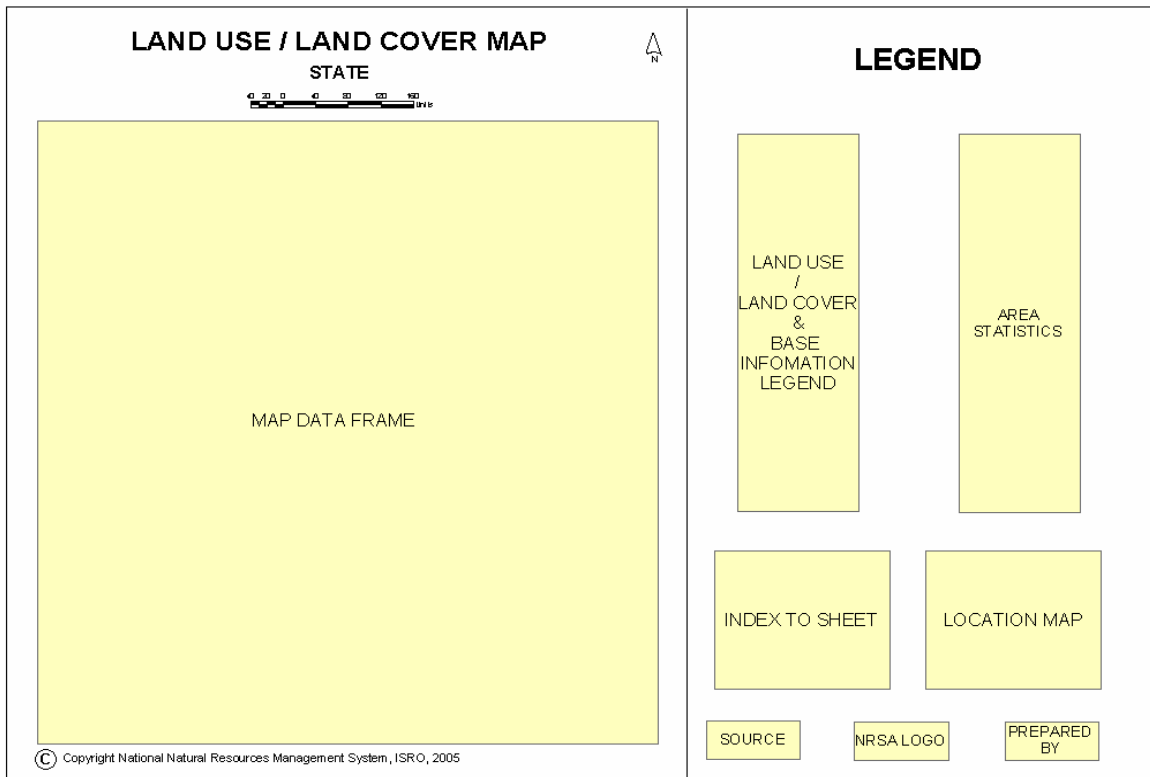


Figure 18. Map template – LU/LC-AWiFS project.

CHAPTER 6**QUALITY ASSURANCE**

This project will contribute significantly towards natural resources census. About nine date data sets (three seasons, three dates per season) would be analyzed to bring out nationwide landuse / landcover map at 1:250,000 scale. In view of importance of this information and to enhance the confidence of users of this information, systematic Quality Assurance (QAS) is planned in the following areas -

- Project Planning
- Geo-rectification
- Classification and Mapping
- Geo-database creation

Quality Assurance essentially includes extensive Quality Control at process and product levels by the respective project investigators (process owners) and intensive Quality Assessment and Evaluation on sample basis by Quality team. In order to assure a quality product, process level quality checks must be carried out to meet set standards. NNRMS standards have been finalized for NRR and the same standards are adapted in this project. The metadata should be properly maintained by these teams to facilitate proper QAS. Metadata on project activities should be maintained by the respective project teams in the prescribed formats. QAS shall be carried out on all the products returned for not meeting the standards, after they are regenerated. The quality assurance and evaluation process has been depicted in Figures 19, 20 & 21.

6.1 QAS for Project Planning

QAS for activities like planning, identification of resources and responsibilities for various project activities are identified.

Periodic (once in a month) project reviews shall be undertaken by the Project Director (PD) on Geo-rectification, Classification & Mapping, Geo-database creation and Quality Assurance. Form 1 Annexure VI shall be filled by Deputy Project Directors (DPD) for reporting project progress to PD. Form 2 Annexure VI shall be filled for every project review and actions taken on decisions of previous review shall be monitored in the next review by PD. The forms are given in the Annexure.

6.2 QAS for Geo-rectification

The geo-rectified quadrants generated by geo-rectification team accompanied by duly filled in Form 5 of Annexure VI (one each for every Quadrant) shall be sent to all the teams within one week of generation. All the quadrants received and rectified by the geo-rectification team once in every two weeks shall be evaluated by QAS team.

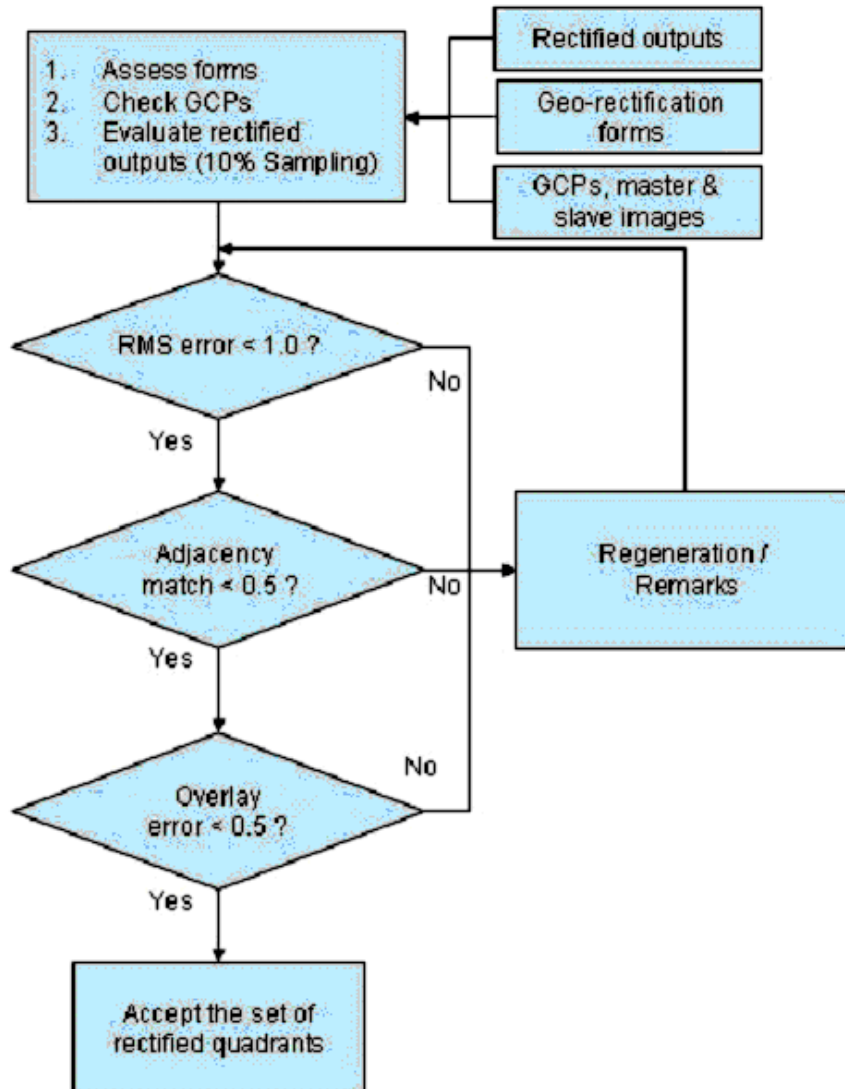


Figure 19. QAS for Geo-rectification

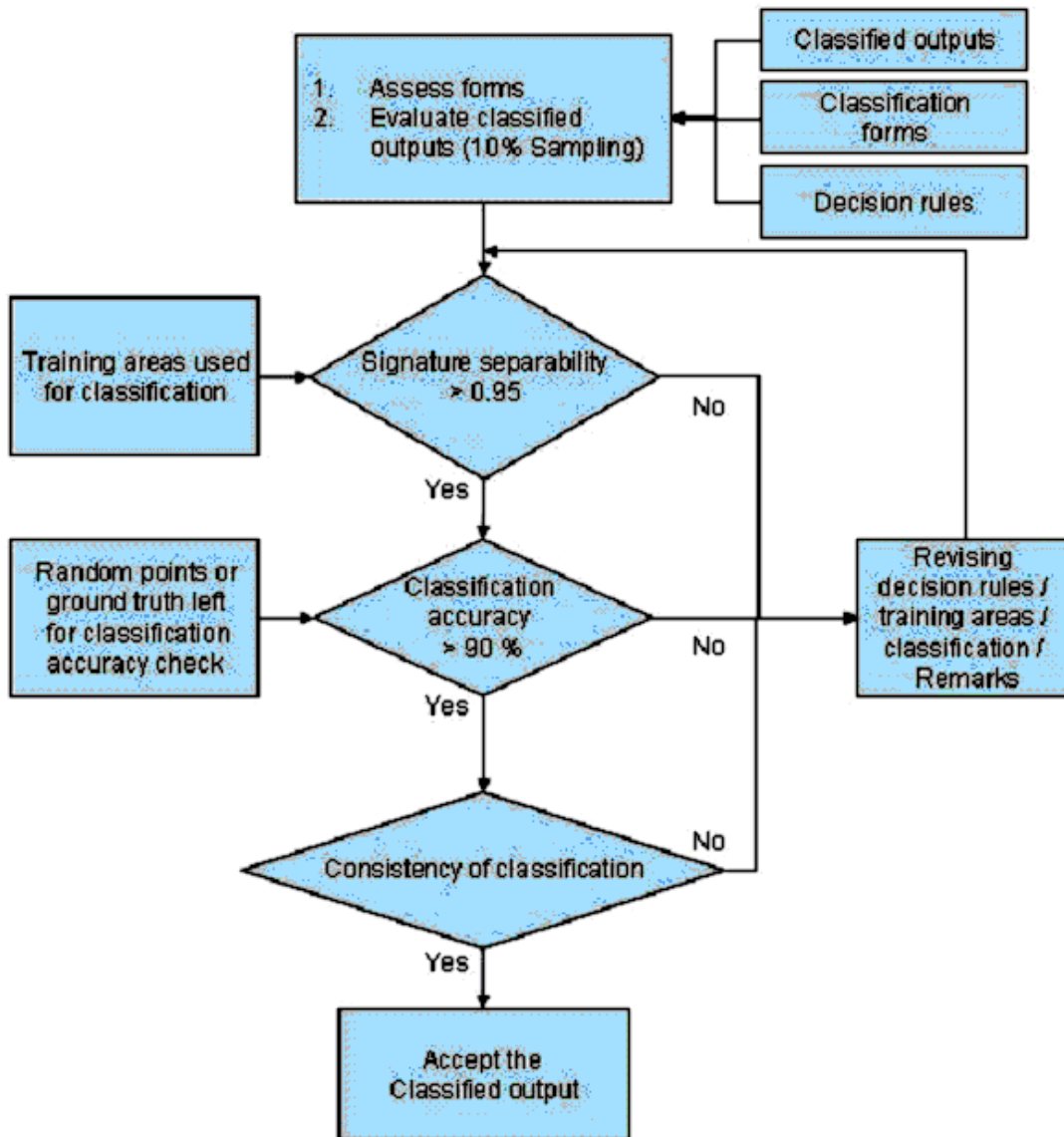


Fig 20. QAS for geodatabase classification

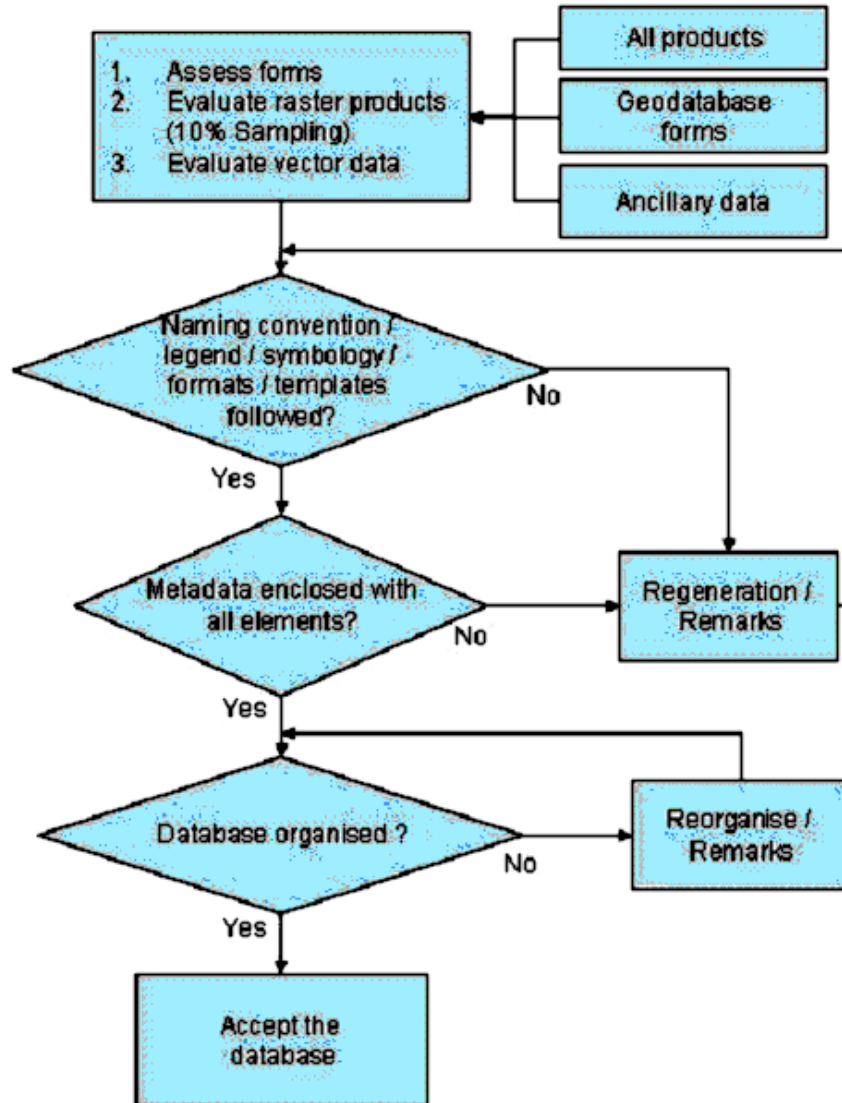


Fig 21 QAS for Geo-database creation

Geo-rectification team shall generate geo-referenced images as per set standards (given in Table 8) with respect to spatial frame work, image quality and geometric accuracy.

Table.8 Standards for Geo-rectification

Parameter	Standard
Projection for image outputs	LCC
Datum for image products	WGS 84
Data resolution	56 m
Cloud cover in the effective area	< 10%
Interpolation technique	NN
Order of transformation	2
Minimum No. of GCPs to be collected	25
Average RMS error for image to master registration	< 1 pixel
Average RMS error for image to image registration	< 0.5 pixel
Error of individual GCP in X or Y direction	< 2 pixels
Position (Planimetric) Accuracy (0.5 mm of scale) in m	125

Source: NNRMS standards

QAS team shall assess all the forms and select 10% of the scenes for every region. The quadrants shall be evaluated for image to image registration by selecting random points on the images. If the registration error of quadrants is not found within the specified limits then further 10% quadrants shall be selected for evaluation. In case discrepancy is found to be beyond permissible limit again, then the whole lot of quadrants shall be sent back to geo-rectification team for corrective action.

6.3 QAS for Thematic classification and statistics

Principal Scientist of classification and mapping team shall ensure that the geo-rectified quadrants are as per set standards before classification and shall fill the information in Forms 6 & 7 of Annexure VI and send to QAS team.

QAS team shall assess the forms received in a fortnight and shall select 10% of the quadrants falling in each region. The quadrants shall be evaluated for classification accuracy at the end of every fortnight. QAS team shall check a minimum of 10 points for each class occupying around 5% of geographical area of the quadrants or part thereof and the number of points will increase in proportion to class area percentage. If the classified outputs are not within the specified limits, then further 10% quadrants shall be selected for evaluation. In case discrepancy beyond set standards (given in Table 9) is found again, then the whole lot shall be rejected and sent back for classification for corrections.

Table 9. Standards for Classification

Minimum Mappable Unit (MMU) (3 x 3 mm of scale) in sq mts	562500
Thematic Accuracy of Classification/Mapping	90/90

Source: NNRMS standards

The information supplied by classification team (forms) shall be verified. Signature separability shall be checked. Confusion matrix is drawn and the accuracy is estimated. The matrix gives information about true class to which the pixel belongs and the class to which it has been mapped. Based on the confusion matrix thus generated, accuracy of classification can be estimated in case of MXL classification.

Mapping accuracy of thematic map is checked by identifying the locations of the points to be sampled on the ground by using 25% of the available ground truth points. In addition to this, experience could be used to verify classification accuracy by using stratified random sampling. Strata are generated to logically divide the area into different categories and then random sampling is performed to select the check points. The qualitative assessment of classification could also be done to finally clear the classified output.

6.4 QAS for Geodatabase creation

Geo-database team will ensure that all the products are as per set standards and shall fill the information in Forms 8 to 13 of Annexure VI.

QAS team will evaluate the final geo-database and will ensure that these are in prescribed format and meet the set standards. The vector layers generated for the project will adhere to the standards given in Table 10.

Table 10. Standards for Geodatabase

Tie-Point Intervals for Spatial Framework	15' X 15'
Coordinate units for Precision	Decimal-Seconds
Projection	LCC
Datum	WGS 84
GIS DB Tic Registration Accuracy (0.25mm of scale) RMS in m	62.5m
Position (Planimetric) Accuracy (1mm of scale) in m	250
Coordinate Movement Tolerance (CMT) (0.125mm of scale) in m (Precision for geo-database)	31.25
Weed Tolerance (WT) (0.125 mm of scale) in m	31.25
Sliver Polygon Tolerance (SPT) (LESS-THAN MMU) in Sq. m	< 562500

Source: NNRMS standards

6.5 QAS for hardcopy generation & statistics

Geo database team will ascertain that the hard copy outputs confirm to the output specifications laid down in the project. The map has to be technically correct and aesthetically beautiful.

QA team shall randomly check the outputs for the parameters given below:

SNo	Parameter	Remarks
1	Overall Contents	
2	Map Components: Map Legend Direction mark Scale Auxiliary information	
3	Symbology adherence to NRCENSUS standards	
4	Aesthetics: Size of map Size of Legend Size of Text used Size of scale bar Placements of these components etc	
5	Measurements for scale check	OK / NOT OK

6.6 Responsibilities

QA team shall share the responsibilities of Quality evaluation (based on parameters listed in Form 14 of Annexure VI) with respect to various centers as given below.

Activity	NRSA	RRSSCJ	IIRSD
Georectification with master	Vinod M Bothale Rajashree V Bothale Saindranath Jonna M A Fyzee Rajeev Jaiswal		
Image-image Georectification	Saindranath Jonna M A Fyzee Rajeev Jaiswal		
Classification & mapping	RajashreeV Bothale Rajeev Jaiswal	Saindranath Jonna M A Fyzee	Vinod M Bothale Rajeev Jaiswal
Geo-database creation	RajashreeV Bothale Rajeev Jaiswal	Saindranath Jonna M A Fyzee	Vinod M Bothale Rajeev Jaiswal

REFERENCES

- Amarnath G., Murthy M.S.R., Britto S.J., Rajashekar G., Dutt C.B.S. 2003. Diagnostic analysis of conservation zones using remote sensing and GIS techniques in wet evergreen forests of Western Ghats – An ecological hotspot, Tamil Nadu, India. *Biodiversity and Conservation* 12: 2331-2359.
- Anonymous , 2004 directory.eoportal.org/pres_SouthAfricanLandCoverDatabaseProject.html
- Benediktsson, J. A., P. H. Swain and O. K. Ersoy, 1990. Neural network approaches versus statistical methods in classification of multisource remote sensing data. *IEEE Transactions on Geoscience and Remote Sensing* 28(4):540–552.
- Benediktsson, J. A., P. H. Swain and O. K. Ersoy, 1993. Conjugate-gradient neural networks in classification of multisource and very-high-dimensional remote sensing data. *International Journal of Remote Sensing* 14:2883–2903.
- Breiman, L., Friedman, J.H., R.A. Olshend and C.J. Stone, 1984. *Classification and regression trees*, Belmont. California, Wadsworth International Group.
- Carpenter, G. A., S. Grossberg and J. H. Reynolds, 1991a. ARTMAP: Supervised real-time learning and classification of nonstationary data by a self-organizing neural network. *Neural Networks* 4:566–588.
- Carpenter, G., M. Gजा, S. Gopal, and C. Woodcock, 1997. ART networks in remote sensing. *IEEE Transactions on Geoscience and Remote Sensing* 35(2):308–325. Bischoff, H., W. Schneider and A. J. Prinz, 1992. Multispectral classification of Landsat-images using neural networks. *IEEE Transactions on Geoscience and Remote Sensing* 30:482–490.
- Congalton, R.G., 1988a. A comparison of sampling schemes used in generating error matrices for assessing the accuracy of maps generated from remotely sensed data, *Photogrammetric Engineering and Remote Sensing*, 54:593-600.
- Congalton, R.G., 1991. A review of assessing the accuracy of classifications of remotely sensed data, *Remote Sensing of Environment*, 37: 35-46.
- Curran, P.J., and Williamson, H.D., 1985. The accuracy of ground data used in remote sensing investigations, *Int. J. Remote Sensing*, 6:1637-1651.
- Curran, P.J., and Williamson, H.D., 1986. Sample size for ground and remotely sensed data, *Remote Sensing of Environment*, 20:31-41.
- DeFries, R., M. Hanson and J. Townshend, 1995. Global discrimination of land cover types from metrics derived from AVHRR pathfinder data. *Remote Sensing of Environment* 54:209–222.
- DeFries, R., M. Hanson, J. Townshend and R. Sohlberg, 1998. Global land cover classifications at 8 km spatial resolutions: The use of training data derived from landsat imagery in decision tree classifiers. *International Journal of Remote Sensing*, 19(6):3141-3168.
- DeFries, R.S. and J. R.G. Townshend. 1994. NDVI-derived land cover classifications at a global scale. *International Journal of Remote Sensing* 15 (17): 3567-3586.
- Fischer, M. M., S. Gopal, P. Staufer, and K. Steinocher, 1997. Evaluation of neural pattern classifiers for a remote sensing application. *Geographical Systems* xx:xxx–xxx.

- Fitzgerald, R. W. and B. G. Lees, 1994. Assessing the classification accuracy of multisource remote sensing data. *Remote Sensing of Environment* 47:362–368.
- Friedl, M. A., and C. E. Brodley, 1997, Decision tree classification of land cover from remotely sensed data. *Remote Sensing of Environment* 61:399–409.
- Friedl, M. A., C. E. Brodley, and A. H. Strahler, 1999. Maximizing land cover classification accuracies produced by decision trees at continental to global scales. *IEEE Transactions on Geoscience and Remote Sensing* 37(2):969–977.
- Friedl, M., W. Woodcock, S. Gopal, D. Muchoney, A. Strahler and C. Barker- Schaaf, 1999. A note on procedures for accuracy assessment in land cover maps derived from AVHRR data. *International Journal of Remote Sensing*, Friedl, M.A., and C. E. Brodley. 1998a. Decision tree classification of land cover from remotely sensed data. *Remote Sensing of Environment* 61: 399-409.
- Ginevan, M.E., 1979. Testing land-use map accuracy: another look, *Photogrammetric Engineering and Remote Sensing*, 45:1371-1377.
- Gopal, S., C. Woodcock and A. H. Strahler, 1996. Fuzzy ARTMAP classification of global land cover from AVHRR data set. *Proceedings of the 1996 International Geoscience and Remote Sensing Symposium*, Lincoln, Nebraska, May 27–31, 1996, 1:538–540.
- Gopal, S., D. M. Sklarew and E. Lambin. 1994. Fuzzy-neural networks in multitemporal classification of land cover change in the Sahel. *New Tools for Spatial Analysis, Proc. of the Workshop*, Lisbon, 18 to 20 November 1993, Office for Official Publ. Eur. Communities, Luxembourg, pp. 69-81.
- Hansen, M., R. Dubayah and R. DeFries, 1996. Classification trees: An alternative to traditional land cover classifiers. *International Journal of Remote Sensing* 17:1075–1081.
- Hatfield, J.L., Kanemasu, E.T., Asrar, G., Jackson, R.D., Pinter, P.J., Reginato, R.J. and Idso, S.B., 1985. Leaf area estimates from spectral measurements over various planting dates of wheat. *Int. J. Remote Sensing*. 6:167-175.
- Hay, A.M., 1979. Sampling designs to test land-use map accuracy, *Photogrammetric Engineering and Remote Sensing*, 45:529-533.
- Hepner, G. F., T. Logan, N. Ritter and N. Bryant, 1990. Artificial neural network classification using a minimal training set: Comparison to conventional supervised classification. *Photogrammetric Engineering and Remote Sensing* 56(4):469–473.
- Hord, M.R., and Brooner, W., 1976. Land-use map accuracy criteria. *Photogrammetric Engineering and Remote Sensing*, 42:671-677.
- IIRS. 2004a. Biome Level Characterization of Indian Vegetation Using IRS - WiFS Data. Pp 166
- IIRS. 2004b. Land Cover Mapping Using SPOT-VEGETATION for South Central Asia. Pp 98
- Justice, C.O., and Townshend, J. G., 1981. Integrating ground data with remote sensing. *Terrain analysis and remote sensing*, (Townshend J.G., editor) George Allen and Uniwin, London.
- Koomanoff, V. A., 1989. Analysis of Global Vegetation Patterns: A Comparison Between Remotely Sensed Data and a Conventional Map. *Biogeography Research Series*, Report

-
- #890201, Department of Geography, University of Maryland.
- Lambin, E. F. and D. Ehrlich, 1996a. The surface temperature-vegetation index space for land cover and land-cover change analysis. *International Journal of Remote Sensing* 17(3):463–487.
- Lambin, E. F. and D. Ehrlich, 1996b. Broad scale land-cover classification and interannual climatic variability. *International Journal of Remote Sensing* 17(5):845–862.
- Lloyd, D., 1990. A phenological classification of terrestrial vegetation cover using shortwave vegetation index imagery. *International Journal Remote Sensing* 11:2269–2279.
- Loveland, T.R., J. W. Merchant, D.O. Ohlen, and J.F. Brown. 1991. Development of a land-cover characteristics database for the conterminous U.S. *Photogrammetric Engineering and Remote Sensing* 57: 1453-1463.
- Lunetta, Ross S., Congalton, Russell G., Lynn, Fenstermaker K., Jensen John R., McGwire Kenneth C. and Tinney Larry R. 1991. Remote sensing and geographic information systems data integration: Error sources and research issues. *Photogrammetric Engineering and Remote Sensing*, 57:677-687.
- Matthews, E., 1983, Global vegetation and land-use: New-high resolution data bases for climate studies. *Journal of Climate and Applied Meteorology* 22:474–487.
- NASA, 2003, http://gcmd.nasa.gov/records/GCMD_1_250_LULC.html
- NRSA, 2002. Integrated Mission for Sustainable Development - Path to Progress. Published by National Remote Sensing Agency, Department of Space, Government of India, Hyderabad – 500 037.
- Olson, J. S., and J. Watts, 1982. Major world ecosystem complexes. In *Earth's Vegetation And Atmospheric Carbon Dioxide*, In *Carbon Dioxide Review*, D. B. Jones (ed.), Oxford University Press, Oxford, pp. 388–399.
- Olson, J. S., J. Watts, and L. Allison, 1983. Carbon in live vegetation of major world ecosystems. Report W-7405-ENG-26, U.S. Dept. of Energy, Oak Ridge National Laboratory, Oak Ridge, TN.
- Quinlan, J. R., 1993, C4.5: Programs for Machine Learning. Morgan Kaufmann, San Mateo, CA.
- Rao, R. S., and Ulaby, F.T., 1977. Optimal sampling techniques for ground truth data in microwave remote sensing of soil moisture. *Remote Sensing of Environment*, 6:289-301.
- Reed, B.D., J.F. Brown, D. VanderZee, T.R. Loveland, J.W. Merchant and D.O. Ohlen. 1994. Measuring phenological variability from satellite imagery. *J. Vegetation Science* 5: 703-714.
- Richard, J.A., 1993. *Remote sensing digital image analysis*. Springer Verlag, Berlin.
- Roy P.S. and Behera M.D. 2005. Assessment of biological richness in different altitudinal zones in the Eastern Himalayas, Arunachal Pradesh, India. *Current Science* 88: 250-256.
- Roy P.S. and Tomar S. 2001. Landscape cover dynamics pattern in Meghalaya. *International Journal of Remote Sensing* 22: 3813 – 3825.
- Safavian, S. R. and D. Landgrebe, 1991, A survey of decision tree classifier methodology. *IEEE Transactions on Systems, Man, and Cybernetics* 21:660–674.
- Swain, P. H., and H. Hauska, 1977. The decision tree classifier: Design and potential. *IEEE Transactions on Geoscience and Remote Sensing*, GE-15:142–147.
- Thomas, I.L., and Allcock, G.McK., 1984. Determining the confidence level for a

-
- classification. *Photogrammetric Engineering and Remote Sensing*, 50:1491-1496.
- Townshend, J. R. G., C. O. Justice, and V. T. Kalb, 1987, Characterization and classification of South American land cover types using satellite data. *International Journal of Remote Sensing* 8:1189–1207.
- Utah Field Crew, 2004. Field Data Collection Protocols for the Southwest Regional GAP Analysis Project.
- Van Genderen, J.L., Lock, B.F., and Vass, P.A., 1978. Remote sensing: statistical testing of thematic map accuracy. *Remote Sensing of Environment*, 7:3-14.
- Wilson, M., and A. Henderson-Sellers, 1985, A global archive of land cover and soils data for use in general circulation climate models. *Journal of Climatology* 5:119– 143.
- Yoshida, T. and S. Omatu, 1994. Neural network approach to land cover mapping. *IEEE Transactions on Geoscience and Remote Sensing* 32:1103–1110.
- Zhou, Q., and Pilesjö, P., 1996, Improving ground truthing for integrating remotely sensed data and GIS. *International Society for Photogrammetry and Remote Sensing. Workshop on New Developments in Geographical Information Systems*, (Milan, Italy, 6-8 March 1996).
- URL's referred:**
- [URL:http://earth.gis.usu.edu/swgap/utgap_fdp.pdf](http://earth.gis.usu.edu/swgap/utgap_fdp.pdf)
- Sara Brogaard and Rannveig Ólafsdóttir 1997. Ground-truths or Ground-lies? Environmental sampling for remote sensing application exemplified by vegetation cover data. **URL:**<http://www.natgeo.lu.se/Publikationer/Lerpg/1/1Article.htm>
- Wu, C, 1991, www.gisdevelopment.net/aars/acrs/2000/ts12/laus0008.shtml

ANNEXURES

ANNEXURE - I

Study 1

A study was conducted to evaluate the positional as well as radiometric accuracies in different projection systems using two sets of AWiFS data – one in Andhra Pradesh latitudes and other in Uttar Pradesh latitudes.

The 1st part of the study was designed to evaluate the positional accuracy. A set of GCPL points were compared to the correspondingly identifiable points in the orthorectified TM data. All the points under evaluation were within the tolerance limits of accuracy i.e. between 30m – 60m. Similar exercise was carried out with (i) orthorectified TM data transformed to geographic coordinates with WGS 84 datum, (ii) geo-rectified AWiFS data transformed to geographic coordinates with WGS 84 datum and (iii) geo-rectified AWiFS data transformed to LCC projection with WGS 84 datum. The error was found to be within 100m in all cases.

The 2nd part of the study was designed to evaluate the changes in radiometry when the AWiFS data was projected into different projections i.e., LCC, UTM, geographic and geographic to LCC. The raw AWiFS (NDC supplied) and projected data sets were classified into 15 classes through digital classification technique (unsupervised). A set of statistical parameters such as minimum (DN value), maximum (DN value), mean (DN value), standard deviation and geographical area under each class were computed. The percent change in area statistics for all the 15 classes were also computed with respect to the raw AWiFS classified data.

The study indicates that the LCC projected data has performed better than UTM and geographic data sets in terms of classification accuracies.

Study 2

Another study was conducted to evaluate the relative positional (locational) accuracy of AWiFS data when projected to LCC projection with two sets of projection parameters keeping the datum same i.e WGS84. These projection parameters were different in terms of standard parallels and origin latitude : one for the country as a whole and the other for each zone (the entire country was divided in to five zones with a latitudinal separation of 8° starting from 0° N to 40° N).

(i) Procedure adopted:

- ❖ Four quadrants of AWiFS data falling one each in the North, South, East and West regions of India were selected (Table-A)
- ❖ Two types of data sets were generated by projecting each AWiFS quadrant as per the standard parallels and other projection parameters defined for the country (India) as well as for each zone (Zonal) (Table-B)

- ❖ In five parts (LL, LR, UL, UR and Center) of each type of the data set, the coordinates of identifiable points were measured and their difference was computed in terms of longitude/latitude
- ❖ The measurements were tabulated (Table-C) for all the four areas identified in the North, South, East and West regions of India

(ii) Observations:

- ❖ The Table-C shows that the relative deviation in the location of various points vary between
 - 5 meters and 112.0 meters in the longitudinal direction
 - 0.3 meters and 68.0 meters in the latitudinal direction

(iii) Conclusions:

- ❖ The study indicates that either of the projection parameters (India or Zonal) can be used for georectification of AWiFS data as the relative deviation in both longitude and latitude directions is much less than 168 meters, prescribed by the Project.

Table A. Data Used

Regions of India covered	Data ID
EAST	110/54 A 15feb05
WEST	95/55 C 19jan05
SOUTH	100/65 B 13feb05
NORTH	95/45 C 19jan05

Table B. Projection parameters used

Geographical Coverage	Parameters for the AWiFS Quadrants studied	
India	SP1	: 35° 10' 22.096" N
	SP2	: 12° 28' 22.638" N
	Central meridian:	80° E
	Origin latitude :	24° N
	False Easting :	4000000
	False Northing:	4000000
ZONE 2 (8° N to 16° N)	SP1	: 10° N
	SP2	: 14° N
	Central meridian:	80° E
	Origin latitude :	12° N
	False Easting :	4000000
	False Northing :	4000000

Zones	ZONE 4 (24° N to 32° N)	SP1 : 26° N SP2 : 30° N Central meridian: 80° E Origin latitude : 28° N False Easting : 4000000 False Northing : 4000000
	ZONE 5 (32° N to 40° N)	SP1 : 34° N SP2 : 38° N Central meridian: 80° E Origin latitude : 36° N False Easting : 4000000 False Northing : 4000000

Table C. Measurements of point locations in AWiFS quadrants

S. No.	Search area on data set	Coordinates of identifiable point on data set				Difference w.r.t Zonal parameters (in seconds)	
		using India parameters		using Zonal parameters		Long	Lat
		Longitude	Latitude	Longitude	Latitude		
1.	AWiFS 11054A_15feb05 (Eastern side of India)						
	Lower Left	88°10'58.37"	26°14'11.17"	88°10'58.14"	26°14'11.90"	-0.23	0.73
	Lower Right	90°28'58.45"	25°22'38.71"	90°28'58.06"	25°22'37.31"	-0.39	-1.40
	Upper Left	88°52'42.66"	28°29'19.76"	88°52'44.14"	28°29'19.21"	1.48	-0.55
	Upper Right	91°58'43.84"	28°04'18.82"	91°58'41.99"	28°04'18.87"	-1.85	0.05
	Center	89°35'48.75"	27°15'20.09"	89°35'49.76"	27°15'22.37"	1.01	2.28
2.	AWiFS 9555C_19jan05 (Western side of India)						
	LL	70°56'14.86"	21°28'46.73"	70°56'14.56"	21°28'45.00"	-0.3	-1.73
	LR	74°07'36.53"	20°57'09.28"	74°07'37.13"	20°57'08.48"	0.6	-0.80
	UL	71°57'26.29"	24°20'41.60"	71°57'27.82"	24°20'41.78"	1.53	0.18
	UR	74°26'53.40"	23°34'32.49"	74°26'53.58"	23°34'33.02"	0.18	0.53
	Center	72°50'49.83"	22°43'12.69"	72°50'49.44"	22°43'12.59"	-0.39	-0.10
3.	AWiFS 10065B_13feb05 (Southern side of India)						
	LL	78°31'22.18"	12°08'20.94"	78°33'22.69"	12°08'22.16"	0.51	1.22
	LR	79°42'00.82"	11°37'00.04"	79°41'59.04"	11°37'00.34"	-1.78	0.3
	UL	78°19'31.88"	14°49'17.20"	78°19'33.92"	14°49'17.21"	2.04	0.01
	UR	80°07'01.69"	14°15'39.92"	80°06'59.55"	14°15'40.47"	-2.14	0.55
	Center	79°08'12.98"	13°17'19.60"	79°08'16.71"	13°17'18.66"	3.73	-0.94
4.	AWiFS 9545C_19jan05 (Northern side of india)						
	LL	74°20'42.49"	33°39'38.32"	74°20'45.41"	33°39'36.84"	2.92	-1.48
	LR	76°59'40.34"	33°18'24.30"	76°59'38.87"	33°18'24.06"	-1.47	-0.24
	UL	74°46'36.09"	35°55'47.37"	74°46'37.78"	35°55'46.71"	1.69	-0.66
	UR	77°32'28.04"	35°33'41.20"	77°32'27.12"	35°33'41.61"	-0.92	0.41
	Center	75°56'02.23"	34°37'56.57"	75°56'02.73"	34°37'57.18"	0.5	0.61

ANNEXURE-II

PRO-FORMA FOR GROUND TRUTH COLLECTION

1.Sat. Data- ID	Quadr. No -	Path / Row -	Date -	
2. Site Details	Observ No -	Date -	Authors -	Season- K / R / S
	GPS Reading	Lat	Long	Elev.
	Village -	Tehsil -	District -	State -
	SOI Map No	Photo no	Land mark	
	Slope (%)	Erosion Type sheet / rill / gully /Ravines	Surface condt. Dry/Moist/Wet	
Sl No.	Land use /Land cover class			Remarks
1	Built up land(Urban / Rural)			
2	Kharif crop land			
3	Rabi crop land			
4	Zaid crop land			
5	Double / triple crop land (Area sown more than once)			
6	Current fallow land			
7	Plantations / orchards			
8	Evergreen / Semi-Evergreen forest			
9	Deciduous forest			
10	Shrub / degraded / Scrub Forest			
11	Littoral Swamp / Mangrove / Fresh water Swamp			
12	Grassland & Grazing Land			
13	Land with shrub / scrub			
14	Land without shrub / scrub			
15	Other Wastelands: Salt Affected Land / Sandy Area / Mine dumps / Industrial waste / Dumps / Barren rock / Stony waste / Sheet rock			
16	Gullied / Ravines			
17	Shifting cultivation areas			
18	Water bodies: Rivers / Streams/Lakes / Ponds / Reservoir / Tanks / Ash pond / Cooling Pond / Wetland / Waterlogged areas			
19	Snow Covered / Glacial area			

ANNEXURE –III

State names and their codes adopted from NRIS

S.NO	STATE NAME	CODE
1	ANDHRA PRADESH	0100
2	ASSAM	0200
3	BIHAR	0300
4	GUJARAT	0400
5	HARYANA	0500
6	HIMACHAL PRADESH	0600
7	JAMMU & KASHMIR	0700
8	KARNATAKA	0800
9	KERALA	0900
10	MADHYA PRADESH	1000
11	MAHARASTRA	1100
12	MANIPUR	1200
13	MEGHALAYA	1300
14	NAGALAND	1400
15	ORRISSA	1500
16	PANJAB	1600
17	RAJASTHAN	1700
18	TAMIL NADU	1800
19	TRIPURA	1900
20	UTTAR PRADESH	2000
21	WEST BENGAL	2100
22	SIKKIM	2200
23	ARUNACHAL PRADESH	3200
24	DELHI	3500
25	GOA	3600
26	MIZORAM	3800
27	PONDICHERRY	3900
28	ANDAMAN & NICOBAR	4000
29	CHADIGARH	4100
30	CHATTISGARH	4200
31	DAMAN & DIU	4300
32	DADRA & NAGAR HAVELI	4400
33	JHARKAND	4500
34	LAKSHADWEEP	4600

ANNEXURE IV

Sample metadata XML file

```

<?xml version="1.0" encoding="UTF-8"?>
<RecProducts>
  <Product>
    <ProductName>REC10056100404.img</ProductName>
    <Satellite>
      <Satellite-id>IRS P6</Satellite-id>
      <Sensor-id>AWiFS</Sensor-id>
      <Path>100</Path>
      <Row>56</Row>
      <Quadrant>A</Quadrant>
      <DateofPass>100404</DateofPass>
    </Satellite>
    <LayerPixels>1024</ LayerPixels >
    <LayerLines>1024</ LayerLines >

    <LayerBands>
      <nobands>4</nobands>
      <bandno>2</bandno>
      <bandno>3</bandno>
      <bandno>4</bandno>
      <bandno>5</bandno>
    </LayerBands>

    <LayerFormat>img</LayerFormat>
    <LayerType>10bit</LayerType>

    <LayerProjections>
      <Projection>LCC</Projection>
      <Datum>WGS 84</Datum>
      <StdParallel1>10</StdParallel1>
      <StdParallel2>14</StdParallel2>
      <CentralMeridian>82</CentralMeridian>
      <FasleEasting>4000000</FalseEasting>
      <FasleNorthing>4000000</FalseNorthing>
      <CLat>12.20</CLat>
      <CLong>76.50</CLong>
      <CLat>11.20</CLat>
      <CLong>77.50</CLong>
    </LayerProjections>

    <PACCLayer_HOR>0.5</ PACCLayer_HOR >
    <ReasonforDeviation> </ReasonforDeviation>
    <StudyArea> </StudyArea>
    <Keywords>
      <Keyword> </Keyword>
  </Product>
</RecProducts>

```

```

    <Keyword> </Keyword>
    <Keyword> </Keyword>
  </Keywords>
  <Quality_Parameters>
    <RefNo>123</RefNo>
    <NDCReqNo>NDC1210</NDCReqNo>
    <TeamID>GEO RECTIFICATION TEAM</TeamID>
    <ProjectCode>1216</ProductCode>
  <ProjectTitle>NATIONAL LEVEL LU/LC MAPPING USING AWIFS</ProjectTitle>
  <StudyLocation>
    <Covered>25</Covered>
    <Covered>25</Covered>
    <Covered>25</Covered>
    <Covered>25</Covered>
  </StudyLoation>
    <RefImage>
      <Resolution>28.5</Resolution>
      <LocationError> <50 </LocationError>
      <ProjectionInfo>
        <Projection>UTM</Projection>
        <Datum>WGS 84</Datum>
      </ProjectionInfo>
    </RefImage>
    <ImageRegistration>
      <GCPs>90</GCPs>
      <GCPDistribution>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
      </GCPDistribution>
      <PolynomialOrder>2</PolynomialOrder>
      <Interpolation>NN</Interpolation>
      <ImagetoImageReg> <0.5 </ImagetoImageReg>
      <AdjacencyMatch> <0.25 </AdjacencyMatch>
    </ImageRegistration>
    <Executor>
      <Name>A.RAVI KUMAR</Name>
      <Date>130305</Date>
    </Exeutor>
    <Verifier>
      <Name>MV.RAVI KUMAR</Name>
      <Date>140305</Date>
    </Verifier>

```

</Quality_Parameters>
</Product>
</RecProducts>

ANNEXURE V

A. Metadata content as per NSDI

S.No.	Metadata description	Metadata name	Purpose
1	NSDI Agencies	NSDIAgency	Authenticated NSDI agencies and their details
2	NSDI Organization-wise Layers	NSDILayers	Registry of layers of NSDI – Agency-wise
3	Grouping of Layers into specific Categories	NSDILayerCategory	Listing of the user categories into which all layers are grouped for user search
4	Spatial Framework - Mapsheets	SpatFrameMap	Listing of the spatial framework of NSDI and applicable for Framework NSDI data
5	Non-Framework-Spatial Data	NonFrameMap	Listing of the framework of NSDI layer which is not Framework compliant and is applicable to Non-Framework NSDI data
6	Spatial Framework - States	SpatFrameState	Listing of all the states and their spatial reference as per the spatial framework
7	Spatial Framework - districts	SpatFrameDist	Listing of all the Dsistricts and their spatial reference as per the spatial framework
8	Spatial Framework - Taluk	SpatFrameTaluk	Listing of all the taluks and their spatial reference as per the spatial framework
9	Spatial Framework – Unique Points	SpatFramePts	Listing of all the unique reference locations and their spatial reference
10	Spatial Framework – User Defined Box	--	To be computed on-line for every user-defined box to find out the area

			of interest and correlating it to the toposheet
11	Attribute Layer Codes	LayerName:LayerEntity (one table for each layer)	Contains description of layer attributes/Entity and their coding schemes
12	Layer Catalogue	LayerCat (for all layers)	Details of layers on mapsheet spatial framework indicating availability and information about spatial data
13	NSDI Metadata User Registration	User_signin	Details of registered users to NSDI metadata
14	NSDI Metadata Access Record	NSDIMetadataAccessRecord	Details of all registered user access to NSDI metadata

B. Metadata for project name and work centers.

S.No.	Metadata name	Fields/ content	Remarks
1	ProjectNames	ProjectName ProjectAcronym ProjectDescription More details to be in a linked table	Each project is one instance of this structure. For this project, the project name is ‘National LULC mapping using AWiFS’ and Project Acronym is ‘LULC-AWiFS’
2	WorkCenters	ProjectAcronym WorkCenterName WorkCenterAcronym WorkCenterAddress	Work Centers are defined for each of the projects in the geodatabase. ProjectName is a foreign key in this structure. For the LULC-AWiFS project, the values for WorkCenterAcronym are NRSA/ RRSSC-J/ IIRS.

C. Georectified quadrant data and TOA corrected quadrant data

Metadata element name	Standard values
Project code	1216
Project Title	National level LU/LC mapping using AWiFS data
User Name	NRR
Product Name	
Satellite-ID	
Sensor-ID	
Path-Row	
Quadrant	
Date of Pass (ddmmyy)	
Pixel Resolution	56 m
No. of Bands	4
Band Nos.	2,3,4,5
Layer Pixels	
Layer Lines	
BrowseLayer	HTML tag to file type JPG
Layer Format	Img/tif
Layer Data Type	Unsigned 10 bit
Reference Image Information pixel resolution location error projection details	28.5m <.50 meters Orthorectified, UTM, WGS84
No. of GCPs	
RMS Error	
Polynomial order	2
Interpolation	NN
Projection	LCC
Datum	WGS 84
Std. Parallel 1	
Std. Parallel 2	
Latitude of Origin	
Central Meridian	
False Easting	
False Northing	
Corner Coordinates: TLLat TLLong LRLat LRLong	
Georectification Done by	

	name date	
Georectification Verified by	name date	
QA Done by	name date	
QA Verified by	name date	
Geodatabase Done by	name date	
Geodatabase Verified by	name date	

D. TOA corrected state mosaic data

Metadata element name	Standard values
Project Code	1216
Project Name	National level LU/LC mapping using AWiFS data
User Name	NRR
Product Name	
Classification Team	
State Name	
Satellite-ID	
Sensor-ID	
Pixel Resolution	
No of quadrants	
Dates of Pass, Path and Rows	
No. of Bands	
Band Nos.	
Layer Pixels	
Layer Lines	
BrowseLayer	HTML tag to file type JPG
Layer Format	Img/tif
Layer Data Type	float
Projection for image outputs	LCC
Datum for image products	WGS 84
Std. Parallel 1	
Std. Parallel 2	

F. GIS Vector data

Metadata element name	Standard values
Project code	1216
Project Title	National level LU/LC mapping using AWiFS data
User Name	NRR
Product Name	
Layer type	Point/line/polygon
Survey year	
Mapping year	
Digitization year	
Layer Scale	50,000/250,000
Layer created with which software	Arc/info
LayerEntity	.lut/.dat
Projection	LCC
Datum	WGS 84
Std. Parallel 1	
Std. Parallel 2	
Latitude of Origin	
Central Meridian	
False Easting	
False Northing	
Corner Coordinates: TLLat TLLong LRLat LRLong	
QA Done by name date	
QA Verified by name date	
Geodatabase Done by name date	
Geodatabase Verified by name date	

ANNEXURE-VI

LULC-AWiFS Project – QA Activity Forms

- Project Planning
- Project Responsibilities
- Project Review
- Progress Report
- Geo-rectification of satellite images
- Classification - Input data
- Classification
- Geodatabase - Rectified data
- Geodatabase - TOA data (Quadrant)
- Geodatabase – TOA data state mosaics
- Geodatabase - Classified data state mosaic
- Geodatabase – Outputs (soft copy)
- Geodatabase – Outputs (hard copy)
- Quality evaluation

Form : 1. Project planning

Ref No. -----

Project Title	<i>National level LU/LC Mapping using AWiFS</i>		
Project Code	<i>1216</i>		
Date of user request and Project Duration			
User Name and address	<i>NRR</i>		
Brief description of user requirements			
List of major activities	Element	Status	Remarks
Feasibility Study	Technically feasible	Yes/No	
	Commercially viable	Yes/No	
	Logistically feasible	Yes/No	
	Security considerations	Yes/No	
Responsibilities: Project Planning			
Responsibilities: DPD Georectification			
Responsibilities: DPD Classification			
Responsibilities: DPD Geodatabase creation			
Responsibilities: DPD Quality evaluation			
Periodical reviewing schedule	Monthly/quarterly/biannual		
Prepared by Name designation, signature and date			
Approved by Name designation, signature and date			

Form : 2. Project responsibilities

Ref No. -----

Project Title		<i>National level LU/LC Mapping using AWiFS</i>	
Project Code		1216	
List of Personnel associated with		Nature of association (Working center/ Designation)	Responsibility
S. no	Name		
1			
2			
3			
4			
5			
Prepared by: Name designation, signature and date			
Ratified by: Name designation, signature and date			

Form : 3. Project review

Ref No. -----

Divisional/Team ID			
Project code	1216		
Project Name	National level LU/LC Mapping using AWiFS		
Meeting no. & date			
Brief description of user requirements			
Previous review record & actions			
Progress achieved	Task	Status	Remarks
Scheduled progress	Task	Status	Remarks
Delayed tasks	Task	Reasons for delay	Tentative completion date
Re-scheduling of tasks required	YES/ No		
Project schedule amendments			
Scheduled date for next review			
Prepared by: by: Name designation, signature and date			
Reviewed by: Name designation, signature and date			

Form : 4. Progress report for -----2005

- 1.Name of PS:
- 2.Names of CPS:
- 3.Study Area:
- 4.No.of Quadrants covering study area

Data browse

Details of cloud-free Quadrants required	Details of cloud-free Quadrants ordered with NDC

Geo-rectification

ACTIVITY	NO OF PRODUCTS COMPLETED	NO OF PRODUCTS IN PROGRESS
Receipt of Std. Product alongwith Request Form		
Precision Geocoding		
Products sent for QC		
QC'd products sent to NDC		
Final Products sent to DPD(C&M)		

Classification & mapping

ACTIVITY	NO OF PRODUCTS COMPLETED	NO OF PRODUCTS IN PROCESS
Receipt of Products from DPD		
Download into system		
TOA Conversion		
Reprojection to LCC		
Ground Truth		
Training Sites Identification		
Classification		
Separability Analysis		
Accuracy Assessment		
Output generation with State Mask		
Area Statistics		
QAS		
Sending to Geodatabase Team		

Geodatabase creation

ACTIVITY	NO OF PRODUCTS COMPLETED	NO OF PRODUCTS IN PROCESS
Metadata Checking		
Dumping into NAS		
Map Composition & Statistics Generation		
QAS		
Output Generation		

Quality Evaluation

ACTIVITY	STATUS	REMARKS
Project review		
Georectification		
Classification		
Geodatabase creation		

Form : 5. Geo-rectification of satellite images

Ref No.	NDC Request no.									
Team ID										
Project Code	1216									
Project Title	National level LU/LC Mapping using AWiFS									
User Name	NRR and DPD, Classification team, LU/LC-AWiFS Project									
Satellite data being used	<p>Sensor <i>AWiFS</i> Spatial resolution <i>56 meters</i> Data Format: <i>IMG</i> Date of Pass Path Row Study area % in each of 2x2 grids covering entire Quadrant:</p> <table border="1" style="float: right; margin-left: 20px;"> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> </table> <p>(only for Quadrants along Indian border)</p>									
Reference Image	<p>Spatial resolution of reference image: <i>28.5 meters</i> Location error in reference image: <i>< 50 meters</i> Projection details: <i>Orthorectified, UTM, WGS84</i></p>									
Image Registration	<p>Total no. of GCPs selected: No. of GCPs in each of 3x3 grids over the Quadrant (8-15%):</p> <table border="1" style="float: right; margin-left: 20px;"> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </table> <p>Order of polynomial used for resampling: <i>2</i> Method of intensity interpolation: <i>NN</i> Average Pixel RMS error (<1 pixel): Average Line RMS error (<1 pixel): Image to image registration error (<0.5 pixel): (for time composite images) Positional accuracy for adjacency match : (for mosaic images)</p>									
Output Image details	<p>Projection: <i>LCC</i> Datum: <i>WGS 84</i></p>									
Executed by: Name designation, signature and date										
Verified by: Name designation, signature and date										

Form : 6. Classification - Input data

Team / State Coordinator / Zone	
Project Code	1216
Project Title	National level LU/LC Mapping using AwiFS
User Name	NRR and DPD, Classification team, LU/LC-AWiFS Project
Satellite data being used	To enter file name as per the file convention standard
Adjacent quadrant numbers	To enter file name as per the file convention standard
Data location (file path)	

Sl	Parameters	Standards to be followed	Standard observed	Remarks by PI
1	Data selection	Kharif (Aug – Nov), Rabi (Jan – Mar), Zaid (Apr – May) Integrated LULC (Aug-May)		
2	Input satellite data			
a	Spatial framework	Projections (LCC) Datum (WGS84) Data format – IMG file with header info.		
b	Input data (Image quality)	Cloud cover Pixel / line dropout Radiometric consistence		
c	Edge matching between quadrants	Sub-pixel accuracy		
d	Registration to Oct 2004	Sub-pixel accuracy		
e	Conversion to reflectance	Comparable ranges in relation to water and sand Procedure given in the manual		

Executed by: Name

Verified by: Name

Designation:

Designation:

Signature & Date:

Signature & Date:

Form : 7. Classification

Team / State Coordinator / Zone	
Project Code	1216
Project Title	National level LU/LC Mapping using Awifs
User Name	NRR and DPD, Classification team, LU/LC Project
Satellite data being used	
Adjacent quadrant numbers	
Data location (file path)	
Season/Integrated LULC	Kharif/Rabi/Zaid/Integrated LULC

Sl	Parameters	Standards to be followed	Standard observed	Remarks by PI
1	Interpretation			
a	Method of classification	Supervised MXL/Decision Tree		
b	No. of training sets	MLC- Minimum of 30 samples per class		
c	Signature separability	Divergence measure (90%)/Decision Tree	Confidence level 90 %	
d	Datasets to be used	Kharif (Aug – Nov), Rabi (Jan – Mar), Zaid (Apr – May) Integrated LULC (Aug- May)		
2	Ground truth			
a	Sampling scheme	Stratified random		
b	Sample size	Min. of 30 samples per class or legacy data		
c	Size of sample site	2.8ha		
d	Subplots	based on ground variation		
3	Classification accuracy			
a	Individual class accuracy	80 – 90%		
b	Over all accuracy	90%		
4	Data mosaicing (State level)			
a	Oct 2005 FCC	Edge matching(100%)		

Executed by: Name

Verified by: Name

Designation:

Designation:

Signature & Date:

Signature & Date:

Form : 8. Geodatabase - Rectified data (Quadrant)

Data set name	img	Ex.:REC10046A100403.IMG
	xml	Ex.:REC10046A100403.XML
Mandatory fields (check whether parameters are filled)		Remarks
Project code	yes/no	
Project Title	yes/no	
User Name	yes/no	
Product Name	yes/no	
Satellite-ID	yes/no	
Sensor-ID	yes/no	
Path-Row	yes/no	
Quadrant	yes/no	
Date of Pass (ddmmyy)	yes/no	
Pixel Resolution	yes/no	
No. of Bands	yes/no	
Band Nos.	yes/no	
Layer Pixels	yes/no	
Layer Lines	yes/no	
Layer Format	yes/no	
Layer Data Type	yes/no	
Reference Image Information (pixel resolution, location)	yes/no	

error, rectification details)			
No. of GCPs		yes/no	
RMS Error		yes/no	
Projection for image outputs	LCC	yes/no	
Datum for image products	WGS 84	yes/no	
Std. Parallel 1		yes/no	
Std. Parallel 2		yes/no	
Central Meridian		yes/no	
False Easting		yes/no	
False Northing		yes/no	
Corner Coordinates: TLLat TLLong LRLat LRLong		yes/no	
Check for well-formedness of metadata in xml format		yes/no	
Executed by: Name			
Signature and Date			
Verified by: Name			
Signature and Date			

Form : 9. Geodatabase - TOA data (Quadrant)

Data set name	img	Ex.:TOA10046A100403.IMG
	Ref. img	Ex.:REC10046A100403.IMG
	xml	Ex.:REC10046A100403.XML
Executed by: Name		
Date		
Verified by: Name		
Date		

Form : 10. Geodatabase - TOA data (State Mosaic)

Data set name	img	Ex.:TOA0100KARF0405.IMG	
	xml	Ex.:TOA0100KARF0405.XML	
Mandatory fields (check whether parameters are filled)			Remarks
Project Code	yes/no		
Project Name	yes/no		
User Name	yes/no		
Product Name	yes/no		
Classification Team	yes/no		
State Name	yes/no		
Satellite-ID	yes/no		
Sensor-ID	yes/no		
Pixel Resolution	yes/no		
No of quadrants	yes/no		
Dates of Pass, Path and Rows	yes/no		
No. of Bands	yes/no		
Band Nos.	yes/no		
Layer Pixels	yes/no		
Layer Lines	yes/no		

Layer Format		yes/no	
Layer Data Type		yes/no	
Projection for image outputs	LCC	yes/no	
Datum for image products	WGS 84	yes/no	
Std. Parallel 1		yes/no	
Std. Parallel 2		yes/no	
Central Meridian		yes/no	
False Easting		yes/no	
False Northing		yes/no	
Corner Coordinates: TLLat TLLong LRLat LRLong		yes/no	
Check for well-formedness of metadata in xml format		yes/no	
Executed by: Name			
Date			
Verified by: Name			
Date			

Form : 11. Geodatabase – Classified data (State mosaic)

Data set name	img	Ex.:CLS0100KARF0405.IMG
	xml	Ex.:CLS0100KARF0405.XML
	Ref. xml	Ex.:TOA0100KARF0405.XML
Mandatory fields (check whether parameters are filled)		Remarks
Project Code	yes/no	
Project Name	yes/no	
User Name	yes/no	
Product Name	yes/no	
Classification Team	yes/no	
State Name	yes/no	
Season	yes/no	
Method of Classification	yes/no	
Data sets used	yes/no	
No. of training sets	yes/no	
Signature separability	yes/no	
Sampling scheme	yes/no	
Sample size	yes/no	
Size of sample site	yes/no	
Subplots	yes/no	
Overall Kappa accuracy	yes/no	
Individual classes Kappa accuracy	yes/no	
Edge matching	yes/no	
Executed by: Name		
Date		
Verified by: Name		
Date		

Form : 12. Geodatabase – Outputs (Softcopy)

Data set name	pdf	
Project Code	1216	
Project Name	<i>National level LU/LC Mapping using AWiFS</i>	
User Name	<i>NRR and DPD Geodatabase team, LU/LC-AWiFS Project</i>	
Geodatabase Team		
Theme Title		
Geographical Area		
Output Scale		
Output size	A0/A3	
Projection	LCC	
Datum	WGS 84	
Std. Parallel 1		
Std. Parallel 2		
Central Meridian		
False Easting		
False Northing		
Framework/Non-framework		
Corner Coordinates: LLLat LLLong URLat URLong		
Elements as per defined format	NRR formats	
Overall Thematic accuracy		
Output Symbology	As per Layer Legend	
Statistics summary		
Executed by: Name Date		
Verified by: Name Date		

Form : 13. Geodatabase – Outputs(Hardcopy)

Data set name	Hard Copy	
Project Code	1216	
Project Name	<i>National level LU/LC Mapping using AWiFS</i>	
User Name	<i>NRR and DPD Geodatabase team, LU/LC-AWiFS Project</i>	
Geodatabase Team		
Theme Title		
Geographical Area		
Output Scale		
Output size	A0/A3	
Projection	LCC	
Datum	WGS 84	
Std. Parallel 1		
Std. Parallel 2		
Central Meridian		
False Easting		
False Northing		
Framework/Non-framework		
Corner Coordinates: LLLat LLLong URLat URLong		
Elements as per defined format	NRR formats	
Overall Thematic accuracy		
Output Symbology	As per Layer Legend	
Statistics summary		
Executed by: Name Date		
Verified by: Name Date		

Form : 14. Quality evaluation

Ref No. -----

Project Title	<i>National level LU/LC Mapping using AWiFS</i>				
Project Code	1216				
Parameters	Prescribed	Claimed	Samples	Achieved	Remarks
A. Project Planning Project schedule Project reviews Project progress User feedback					
B. Image registration Image quality Cloud cover over study area Pixel / line drop out: Registration of images No. of GCPs RMS error Positional accuracy Mosaic Shift (X & Y)					
C. Image Classification Ground truth collection Dates and duration Samples Distribution Classification Accuracy Training areas separability Kappa Accuracy					

<p>D. Geodatabase</p> <p>Legend</p> <p>Format</p> <p>Identification</p> <p>Authorisation</p> <p>Data sets availability</p>					
<p>E. Geodatabase – Output</p> <p>Map components</p> <p>Aesthetics</p> <p>Symbology followed</p>					
<p>Quality evaluated by: Name designation, signature and date</p>					
<p>Evaluation Authorised by Name designation, signature and date</p>					

ANNEXURE

Study 1

A study was conducted to evaluate the positional as well as radiometric accuracies in different projection systems using two sets of AWiFS data – one in Andhra Pradesh latitudes and other in Uttar Pradesh latitudes.

The 1st part of the study was designed to evaluate the positional accuracy. A set of GCPL points were compared to the correspondingly identifiable points in the orthorectified TM data. All the points under evaluation were within the tolerance limits of accuracy i.e. between 30m – 60m. Similar exercise was carried out with (i) orthorectified TM data transformed to geographic coordinates with WGS 84 datum, (ii) geo-rectified AWiFS data transformed to geographic coordinates with WGS 84 datum and (iii) geo-rectified AWiFS data transformed to LCC projection with WGS 84 datum. The error was found to be within 100m in all cases.

The 2nd part of the study was designed to evaluate the changes in radiometry when the AWiFS data was projected into different projections i.e., LCC, UTM, geographic and geographic to LCC. The raw AWiFS (NDC supplied) and projected data sets were classified into 15 classes through digital classification technique (unsupervised). A set of statistical parameters such as minimum (DN value), maximum (DN value), mean (DN value), standard deviation and geographical area under each class were computed. The percent change in area statistics for all the 15 classes were also computed with respect to the raw AWiFS classified data.

The study indicates that the LCC projected data has performed better than UTM and geographic data sets in terms of classification accuracies.

Study 2

Another study was conducted to evaluate the relative positional (locational) accuracy of AWiFS data when projected to LCC projection with two sets of projection parameters keeping the datum same i.e WGS84. These projection parameters were different in terms of standard parallels and origin latitude : one for the country as a whole and the other for each zone (the entire country was divided in to five zones with a latitudinal separation of 8° starting from 0° N to 40° N).

(i) Procedure adopted:

- ❖ Four quadrants of AWiFS data falling one each in the North, South, East and West regions of India were selected (Table-A)
- ❖ Two types of data sets were generated by projecting each AWiFS quadrant as per the standard parallels and other projection parameters defined for the country (India) as well as for each zone (Zonal) (Table-B)

- ❖ In five parts (LL, LR, UL, UR and Center) of each type of the data set, the coordinates of identifiable points were measured and their difference was computed in terms of longitude/latitude
- ❖ The measurements were tabulated (Table-C) for all the four areas identified in the North, South, East and West regions of India

(ii) Observations:

- ❖ The Table-C shows that the relative deviation in the location of various points vary between
 - 5 meters and 112.0 meters in the longitudinal direction
 - 0.3 meters and 68.0 meters in the latitudinal direction

(iii) Conclusions:

- ❖ The study indicates that either of the projection parameters (India or Zonal) can be used for georectification of AWiFS data as the relative deviation in both longitude and latitude directions is much less than 168 meters, prescribed by the Project.

Table A. Data Used

Regions of India covered	Data ID
EAST	110/54 A 15feb05
WEST	95/55 C 19jan05
SOUTH	100/65 B 13feb05
NORTH	95/45 C 19jan05

Table B. Projection parameters used

Geographical Coverage	Parameters for the AWiFS Quadrants studied	
India	SP1 : 35° 10' 22.096" N SP2 : 12° 28' 22.638" N Central meridian: 80° E Origin latitude : 24° N False Easting : 4000000 False Northing: 4000000	
Zones	ZONE 2 (8° N to 16° N)	SP1 : 10° N SP2 : 14° N Central meridian: 80° E Origin latitude : 12° N False Easting : 4000000 False Northing : 4000000
	ZONE 4 (24° N to 32° N)	SP1 : 26° N SP2 : 30° N Central meridian: 80° E Origin latitude : 28° N False Easting : 4000000 False Northing : 4000000
	ZONE 5 (32° N to 40° N)	SP1 : 34° N SP2 : 38° N Central meridian: 80° E Origin latitude : 36° N False Easting : 4000000 False Northing : 4000000

Table C. Measurements of point locations in AWiFS quadrants

S. No.	Search area on data set	Coordinates of identifiable point on data set				Difference w.r.t Zonal parameters (in seconds)	
		using India parameters		using Zonal parameters		Long	Lat
		Longitude	Latitude	Longitude	Latitude		
1.	AWiFS 11054A_15feb05 (Eastern side of India)						
	Lower Left	88°10'58.37"	26°14'11.17"	88°10'58.14"	26°14'11.90"	-0.23	0.73
	Lower Right	90°28'58.45"	25°22'38.71"	90°28'58.06"	25°22'37.31"	-0.39	-1.40
	Upper Left	88°52'42.66"	28°29'19.76"	88°52'44.14"	28°29'19.21"	1.48	-0.55
	Upper Right	91°58'43.84"	28°04'18.82"	91°58'41.99"	28°04'18.87"	-1.85	0.05
	Center	89°35'48.75"	27°15'20.09"	89°35'49.76"	27°15'22.37"	1.01	2.28
2.	AWiFS 9555C_19jan05 (Western side of India)						
	LL	70°56'14.86"	21°28'46.73"	70°56'14.56"	21°28'45.00"	-0.3	-1.73
	LR	74°07'36.53"	20°57'09.28"	74°07'37.13"	20°57'08.48"	0.6	-0.80
	UL	71°57'26.29"	24°20'41.60"	71°57'27.82"	24°20'41.78"	1.53	0.18
	UR	74°26'53.40"	23°34'32.49"	74°26'53.58"	23°34'33.02"	0.18	0.53
	Center	72°50'49.83"	22°43'12.69"	72°50'49.44"	22°43'12.59"	-0.39	-0.10
3.	AWiFS 10065B_13feb05 (Southern side of India)						
	LL	78°31'22.18"	12°08'20.94"	78°33'22.69"	12°08'22.16"	0.51	1.22
	LR	79°42'00.82"	11°37'00.04"	79°41'59.04"	11°37'00.34"	-1.78	0.3
	UL	78°19'31.88"	14°49'17.20"	78°19'33.92"	14°49'17.21"	2.04	0.01
	UR	80°07'01.69"	14°15'39.92"	80°06'59.55"	14°15'40.47"	-2.14	0.55
	Center	79°08'12.98"	13°17'19.60"	79°08'16.71"	13°17'18.66"	3.73	-0.94
4.	AWiFS 9545C_19jan05 (Northern side of india)						
	LL	74°20'42.49"	33°39'38.32"	74°20'45.41"	33°39'36.84"	2.92	-1.48
	LR	76°59'40.34"	33°18'24.30"	76°59'38.87"	33°18'24.06"	-1.47	-0.24
	UL	74°46'36.09"	35°55'47.37"	74°46'37.78"	35°55'46.71"	1.69	-0.66
	UR	77°32'28.04"	35°33'41.20"	77°32'27.12"	35°33'41.61"	-0.92	0.41
	Center	75°56'02.23"	34°37'56.57"	75°56'02.73"	34°37'57.18"	0.5	0.61

ANNEXURE-II

PRO-FORMA FOR GROUND TRUTH COLLECTION

1.Sat. Data- ID	Quadr. No -	Path / Row -	Date -	
2. Site Details	Observ No -	Date -	Authors -	Season- K / R / S
	GPS Reading	Lat	Long	Elev.
	Village -	Tehsil -	District -	State -
	SOI Map No	Photo no	Land mark	
	Slope (%)	Erosion Type sheet / rill / gully /Ravines	Surface condt. Dry/Moist/Wet	
Sl No.	Land use /Land cover class			Remarks
1	Built up land(Urban / Rural)			
2	Kharif crop land			
3	Rabi crop land			
4	Zaid crop land			
5	Double / triple crop land (Area sown more than once)			
6	Current fallow land			
7	Plantations / orchards			
8	Evergreen / Semi-Evergreen forest			
9	Deciduous forest			
10	Shrub / degraded / Scrub Forest			
11	Littoral Swamp / Mangrove / Fresh water Swamp			
12	Grassland & Grazing Land			
13	Land with shrub / scrub			
14	Land without shrub / scrub			
15	Other Wastelands: Salt Affected Land / Sandy Area / Mine dumps / Industrial waste / Dumps / Barren rock / Stony waste / Sheet rock			
16	Gullied / Ravines			
17	Shifting cultivation areas			
18	Water bodies: Rivers / Streams/Lakes / Ponds / Reservoir / Tanks / Ash pond / Cooling Pond / Wetland / Waterlogged areas			
19	Snow Covered / Glacial area			

ANNEXURE –III

State names and their codes adopted from NRIS

S.NO	STATE NAME	CODE
1	ANDHRA PRADESH	0100
2	ASSAM	0200
3	BIHAR	0300
4	GUJARAT	0400
5	HARYANA	0500
6	HIMACHAL PRADESH	0600
7	JAMMU & KASHMIR	0700
8	KARNATAKA	0800
9	KERALA	0900
10	MADHYA PRADESH	1000
11	MAHARASTRA	1100
12	MANIPUR	1200
13	MEGHALAYA	1300
14	NAGALAND	1400
15	ORRISSA	1500
16	PANJAB	1600
17	RAJASTHAN	1700
18	TAMIL NADU	1800
19	TRIPURA	1900
20	UTTAR PRADESH	2000
21	WEST BENGAL	2100
22	SIKKIM	2200
23	ARUNACHAL PRADESH	3200
24	DELHI	3500
25	GOA	3600
26	MIZORAM	3800
27	PONDICHERRY	3900
28	ANDAMAN & NICOBAR	4000
29	CHADIGARH	4100
30	CHATTISGARH	4200
31	DAMAN & DIU	4300
32	DADRA & NAGAR HAVELI	4400
33	JHARKAND	4500
34	LAKSHADWEEP	4600

ANNEXURE IV

Sample metadata XML file

```

<?xml version="1.0" encoding="UTF-8"?>
<RecProducts>
  <Product>
    <ProductName>REC10056100404.img</ProductName>
    <Satellite>
      <Satellite-id>IRS P6</Satellite-id>
      <Sensor-id>AWiFS</Sensor-id>
      <Path>100</Path>
      <Row>56</Row>
      <Quadrant>A</Quadrant>
      <DateofPass>100404</DateofPass>
    </Satellite>
    <LayerPixels>1024</ LayerPixels >
    <LayerLines>1024</ LayerLines >

    <LayerBands>
      <nobands>4</nobands>
      <bandno>2</bandno>
      <bandno>3</bandno>
      <bandno>4</bandno>
      <bandno>5</bandno>
    </LayerBands>

    <LayerFormat>img</LayerFormat>
    <LayerType>10bit</LayerType>

    <LayerProjections>
      <Projection>LCC</Projection>
      <Datum>WGS 84</Datum>
      <StdParallel1>10</StdParallel1>
      <StdParallel2>14</StdParallel2>
      <CentralMeridian>82</CentralMeridian>
      <FasleEasting>4000000</FalseEasting>
      <FasleNorthing>4000000</FalseNorthing>
      <CLat>12.20</CLat>
      <CLong>76.50</CLong>
      <CLat>11.20</CLat>
      <CLong>77.50</CLong>
    </LayerProjections>

    <PACCLayer_HOR>0.5</ PACCLayer_HOR >
    <ReasonforDeviation> </ReasonforDeviation>
    <StudyArea> </StudyArea>
    <Keywords>
      <Keyword> </Keyword>
  </Product>
</RecProducts>

```

```

    <Keyword> </Keyword>
    <Keyword> </Keyword>
  </Keywords>
  <Quality_Parameters>
    <RefNo>123</RefNo>
    <NDCReqNo>NDC1210</NDCReqNo>
    <TeamID>GEO RECTIFICATION TEAM</TeamID>
    <ProjectCode>1216</ProductCode>
  <ProjectTitle>NATIONAL LEVEL LU/LC MAPPING USING AWIFS</ProjectTitle>
  <StudyLocation>
    <Covered>25</Covered>
    <Covered>25</Covered>
    <Covered>25</Covered>
    <Covered>25</Covered>
  </StudyLoation>
    <RefImage>
      <Resolution>28.5</Resolution>
      <LocationError> <50 </LocationError>
      <ProjectionInfo>
        <Projection>UTM</Projection>
        <Datum>WGS 84</Datum>
      </ProjectionInfo>
    </RefImage>
    <ImageRegistration>
      <GCPs>90</GCPs>
      <GCPDistribution>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
        <GridGcps>10</GridGcps>
      </GCPDistribution>
      <PolynomialOrder>2</PolynomialOrder>
      <Interpolation>NN</Interpolation>
      <ImagetoImageReg> <0.5 </ImagetoImageReg>
      <AdjacencyMatch> <0.25 </AdjacencyMatch>
    </ImageRegistration>
  <Executor>
    <Name>A.RAVI KUMAR</Name>
    <Date>130305</Date>
  </Exeutor>
  <Verifier>
    <Name>MV.RAVI KUMAR</Name>
    <Date>140305</Date>
  </Verifier>

```

</Quality_Parameters>
</Product>
</RecProducts>

ANNEXURE V

A. Metadata content as per NSDI

S.No.	Metadata description	Metadata name	Purpose
1	NSDI Agencies	NSDIAgency	Authenticated NSDI agencies and their details
2	NSDI Organization-wise Layers	NSDILayers	Registry of layers of NSDI – Agency-wise
3	Grouping of Layers into specific Categories	NSDILayerCategory	Listing of the user categories into which all layers are grouped for user search
4	Spatial Framework - Mapsheets	SpatFrameMap	Listing of the spatial framework of NSDI and applicable for Framework NSDI data
5	Non-Framework-Spatial Data	NonFrameMap	Listing of the framework of NSDI layer which is not Framework compliant and is applicable to Non-Framework NSDI data
6	Spatial Framework - States	SpatFrameState	Listing of all the states and their spatial reference as per the spatial framework
7	Spatial Framework - districts	SpatFrameDist	Listing of all the Dsistricts and their spatial reference as per the spatial framework
8	Spatial Framework - Taluk	SpatFrameTaluk	Listing of all the taluks and their spatial reference as per the spatial framework
9	Spatial Framework – Unique Points	SpatFramePts	Listing of all the unique reference locations and their spatial reference
10	Spatial Framework – User Defined Box	--	To be computed on-line for every user-defined box to find out the area

			of interest and correlating it to the toposheet
11	Attribute Layer Codes	LayerName:LayerEntity (one table for each layer)	Contains description of layer attributes/Entity and their coding schemes
12	Layer Catalogue	LayerCat (for all layers)	Details of layers on mapsheet spatial framework indicating availability and information about spatial data
13	NSDI Metadata User Registration	User_signin	Details of registered users to NSDI metadata
14	NSDI Metadata Access Record	NSDIMetadataAccessRecord	Details of all registered user access to NSDI metadata

B. Metadata for project name and work centers.

S.No.	Metadata name	Fields/ content	Remarks
1	ProjectNames	ProjectName ProjectAcronym ProjectDescription More details to be in a linked table	Each project is one instance of this structure. For this project, the project name is 'National LULC mapping using AWiFS' and Project Acronym is 'LULC-AWiFS'
2	WorkCenters	ProjectAcronym WorkCenterName WorkCenterAcronym WorkCenterAddress	Work Centers are defined for each of the projects in the geodatabase. ProjectName is a foreign key in this structure. For the LULC-AWiFS project, the values for WorkCenterAcronym are NRSA/ RRSSC-J/ IIRS.

C. Georectified quadrant data and TOA corrected quadrant data

Metadata element name	Standard values
Project code	1216
Project Title	National level LU/LC mapping using AWiFS data
User Name	NRR
Product Name	
Satellite-ID	
Sensor-ID	
Path-Row	
Quadrant	
Date of Pass (ddmmyy)	
Pixel Resolution	56 m
No. of Bands	4
Band Nos.	2,3,4,5
Layer Pixels	
Layer Lines	
BrowseLayer	HTML tag to file type JPG
Layer Format	Img/tif
Layer Data Type	Unsigned 10 bit
Reference Image Information pixel resolution location error projection details	28.5m <.50 meters Orthorectified, UTM, WGS84
No. of GCPs	
RMS Error	
Polynomial order	2
Interpolation	NN
Projection	LCC
Datum	WGS 84
Std. Parallel 1	
Std. Parallel 2	
Latitude of Origin	
Central Meridian	
False Easting	
False Northing	
Corner Coordinates: TLLat TLLong LRLat LRLong	
Georectification Done by	

	name date	
Georectification Verified by	name date	
QA Done by	name date	
QA Verified by	name date	
Geodatabase Done by	name date	
Geodatabase Verified by	name date	

D. TOA corrected state mosaic data

Metadata element name	Standard values
Project Code	1216
Project Name	National level LU/LC mapping using AWiFS data
User Name	NRR
Product Name	
Classification Team	
State Name	
Satellite-ID	
Sensor-ID	
Pixel Resolution	
No of quadrants	
Dates of Pass, Path and Rows	
No. of Bands	
Band Nos.	
Layer Pixels	
Layer Lines	
BrowseLayer	HTML tag to file type JPG
Layer Format	Img/tif
Layer Data Type	float
Projection for image outputs	LCC
Datum for image products	WGS 84
Std. Parallel 1	
Std. Parallel 2	

Latitude of Origin	
Central Meridian	
False Easting	
False Northing	
Corner Coordinates: TLLat TLLon LRLat LRLong	
State Name	
Season	
Method of Classification	
Data sets used	
No of training sets	
Signature separability	
Sampling scheme	
Sample size	
Size of sample site	
Subplots	
Overall Kappa accuracy	
Individual classes Kappa accuracy	
Edge matching	
Class statistics	
Classification Done by name date	
Classification Verified by name date	
QA Done by name date	
QA Verified by name date	
Geodatabase Done by name date	
Geodatabase Verified by name date	

F. GIS Vector data

Metadata element name	Standard values
Project code	1216
Project Title	National level LU/LC mapping using AWiFS data
User Name	NRR
Product Name	
Layer type	Point/line/polygon
Survey year	
Mapping year	
Digitization year	
Layer Scale	50,000/250,000
Layer created with which software	Arc/info
LayerEntity	.lut/.dat
Projection	LCC
Datum	WGS 84
Std. Parallel 1	
Std. Parallel 2	
Latitude of Origin	
Central Meridian	
False Easting	
False Northing	
Corner Coordinates: TLLat TLLong LRLat LRLong	
QA Done by name date	
QA Verified by name date	
Geodatabase Done by name date	
Geodatabase Verified by name date	

ANNEXURE-VI

LULC-AWiFS Project – QA Activity Forms

- Project Planning
- Project Responsibilities
- Project Review
- Progress Report
- Geo-rectification of satellite images
- Classification - Input data
- Classification
- Geodatabase - Rectified data
- Geodatabase - TOA data (Quadrant)
- Geodatabase – TOA data state mosaics
- Geodatabase - Classified data state mosaic
- Geodatabase – Outputs (soft copy)
- Geodatabase – Outputs (hard copy)
- Quality evaluation

Form : 1. Project planning

Ref No. -----

Project Title	<i>National level LU/LC Mapping using AWiFS</i>		
Project Code	<i>1216</i>		
Date of user request and Project Duration			
User Name and address	<i>NRR</i>		
Brief description of user requirements			
List of major activities	Element	Status	Remarks
Feasibility Study	Technically feasible	Yes/No	
	Commercially viable	Yes/No	
	Logistically feasible	Yes/No	
	Security considerations	Yes/No	
Responsibilities: Project Planning			
Responsibilities: DPD Georectification			
Responsibilities: DPD Classification			
Responsibilities: DPD Geodatabase creation			
Responsibilities: DPD Quality evaluation			
Periodical reviewing schedule	Monthly/quarterly/biannual		
Prepared by Name designation, signature and date			
Approved by Name designation, signature and date			

Form : 2. Project responsibilities

Ref No. -----

Project Title		<i>National level LU/LC Mapping using AWiFS</i>	
Project Code		<i>1216</i>	
List of Personnel associated with		Nature of association (Working center/ Designation)	Responsibility
S. no	Name		
1			
2			
3			
4			
5			
Prepared by: Name designation, signature and date			
Ratified by: Name designation, signature and date			

Form : 3. Project review

Ref No. -----

Divisional/Team ID			
Project code	1216		
Project Name	National level LU/LC Mapping using AWiFS		
Meeting no. & date			
Brief description of user requirements			
Previous review record & actions			
Progress achieved	Task	Status	Remarks
Scheduled progress	Task	Status	Remarks
Delayed tasks	Task	Reasons for delay	Tentative completion date
Re-scheduling of tasks required	YES/ No		
Project schedule amendments			
Scheduled date for next review			
Prepared by: by: Name designation, signature and date			
Reviewed by: Name designation, signature and date			

Form : 4. Progress report for -----2005

- 1.Name of PS:
- 2.Names of CPS:
- 3.Study Area:
- 4.No.of Quadrants covering study area

Data browse

Details of cloud-free Quadrants required	Details of cloud-free Quadrants ordered with NDC

Geo-rectification

ACTIVITY	NO OF PRODUCTS COMPLETED	NO OF PRODUCTS IN PROGRESS
Receipt of Std. Product alongwith Request Form		
Precision Geocoding		
Products sent for QC		
QC'd products sent to NDC		
Final Products sent to DPD(C&M)		

Classification & mapping

ACTIVITY	NO OF PRODUCTS COMPLETED	NO OF PRODUCTS IN PROCESS
Receipt of Products from DPD		
Download into system		
TOA Conversion		
Reprojection to LCC		
Ground Truth		
Training Sites Identification		
Classification		
Separability Analysis		
Accuracy Assessment		
Output generation with State Mask		
Area Statistics		
QAS		
Sending to Geodatabase Team		

Geodatabase creation

ACTIVITY	NO OF PRODUCTS COMPLETED	NO OF PRODUCTS IN PROCESS
Metadata Checking		
Dumping into NAS		
Map Composition & Statistics Generation		
QAS		
Output Generation		

Quality Evaluation

ACTIVITY	STATUS	REMARKS
Project review		
Georectification		
Classification		
Geodatabase creation		

Form : 5. Geo-rectification of satellite images

Ref No.	NDC Request no.									
Team ID										
Project Code	1216									
Project Title	National level LU/LC Mapping using AWiFS									
User Name	NRR and DPD, Classification team, LU/LC-AWiFS Project									
Satellite data being used	<p>Sensor <i>AWiFS</i> Spatial resolution <i>56 meters</i> Data Format: <i>IMG</i> Date of Pass Path Row Study area % in each of 2x2 grids covering entire Quadrant:</p> <table border="1" style="float: right; margin-left: 20px;"> <tr><td> </td><td> </td></tr> <tr><td> </td><td> </td></tr> </table> <p>(only for Quadrants along Indian border)</p>									
Reference Image	<p>Spatial resolution of reference image: <i>28.5 meters</i> Location error in reference image: <i>< 50 meters</i> Projection details: <i>Orthorectified, UTM, WGS84</i></p>									
Image Registration	<p>Total no. of GCPs selected: No. of GCPs in each of 3x3 grids over the Quadrant (8-15%):</p> <table border="1" style="float: right; margin-left: 20px;"> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td></tr> </table> <p>Order of polynomial used for resampling: <i>2</i> Method of intensity interpolation: <i>NN</i> Average Pixel RMS error (<1 pixel): Average Line RMS error (<1 pixel): Image to image registration error (<0.5 pixel): (for time composite images) Positional accuracy for adjacency match : (for mosaic images)</p>									
Output Image details	<p>Projection: <i>LCC</i> Datum: <i>WGS 84</i></p>									
Executed by: Name designation, signature and date										
Verified by: Name designation, signature and date										

Form : 6. Classification - Input data

Team / State Coordinator / Zone	
Project Code	1216
Project Title	National level LU/LC Mapping using AwiFS
User Name	NRR and DPD, Classification team, LU/LC-AWiFS Project
Satellite data being used	To enter file name as per the file convention standard
Adjacent quadrant numbers	To enter file name as per the file convention standard
Data location (file path)	

Sl	Parameters	Standards to be followed	Standard observed	Remarks by PI
1	Data selection	Kharif (Aug – Nov), Rabi (Jan – Mar), Zaid (Apr – May) Integrated LULC (Aug-May)		
2	Input satellite data			
a	Spatial framework	Projections (LCC) Datum (WGS84) Data format – IMG file with header info.		
b	Input data (Image quality)	Cloud cover Pixel / line dropout Radiometric consistence		
c	Edge matching between quadrants	Sub-pixel accuracy		
d	Registration to Oct 2004	Sub-pixel accuracy		
e	Conversion to reflectance	Comparable ranges in relation to water and sand Procedure given in the manual		

Executed by: Name

Verified by: Name

Designation:

Designation:

Signature & Date:

Signature & Date:

Form : 7. Classification

Team / State Coordinator / Zone	
Project Code	1216
Project Title	National level LU/LC Mapping using Awifs
User Name	NRR and DPD, Classification team, LU/LC Project
Satellite data being used	
Adjacent quadrant numbers	
Data location (file path)	
Season/Integrated LULC	Kharif/Rabi/Zaid/Integrated LULC

Sl	Parameters	Standards to be followed	Standard observed	Remarks by PI
1	Interpretation			
a	Method of classification	Supervised MXL/Decision Tree		
b	No. of training sets	MLC- Minimum of 30 samples per class		
c	Signature separability	Divergence measure (90%)/Decision Tree	Confidence level 90 %	
d	Datasets to be used	Kharif (Aug – Nov), Rabi (Jan – Mar), Zaid (Apr – May) Integrated LULC (Aug- May)		
2	Ground truth			
a	Sampling scheme	Stratified random		
b	Sample size	Min. of 30 samples per class or legacy data		
c	Size of sample site	2.8ha		
d	Subplots	based on ground variation		
3	Classification accuracy			
a	Individual class accuracy	80 – 90%		
b	Over all accuracy	90%		
4	Data mosaicing (State level)			
a	Oct 2005 FCC	Edge matching(100%)		

Executed by: Name

Verified by: Name

Designation:

Designation:

Signature & Date:

Signature & Date:

Form : 8. Geodatabase - Rectified data (Quadrant)

Data set name	img	Ex.:REC10046A100403.IMG
	xml	Ex.:REC10046A100403.XML
Mandatory fields (check whether parameters are filled)		Remarks
Project code	yes/no	
Project Title	yes/no	
User Name	yes/no	
Product Name	yes/no	
Satellite-ID	yes/no	
Sensor-ID	yes/no	
Path-Row	yes/no	
Quadrant	yes/no	
Date of Pass (ddmmyy)	yes/no	
Pixel Resolution	yes/no	
No. of Bands	yes/no	
Band Nos.	yes/no	
Layer Pixels	yes/no	
Layer Lines	yes/no	
Layer Format	yes/no	
Layer Data Type	yes/no	
Reference Image Information (pixel resolution, location)	yes/no	

error, rectification details)			
No. of GCPs		yes/no	
RMS Error		yes/no	
Projection for image outputs	LCC	yes/no	
Datum for image products	WGS 84	yes/no	
Std. Parallel 1		yes/no	
Std. Parallel 2		yes/no	
Central Meridian		yes/no	
False Easting		yes/no	
False Northing		yes/no	
Corner Coordinates: TLLat TLLong LRLat LRLong		yes/no	
Check for well-formedness of metadata in xml format		yes/no	
Executed by: Name			
Signature and Date			
Verified by: Name			
Signature and Date			

Form : 9. Geodatabase - TOA data (Quadrant)

Data set name	img	Ex.:TOA10046A100403.IMG
	Ref. img	Ex.:REC10046A100403.IMG
	xml	Ex.:REC10046A100403.XML
Executed by: Name		
Date		
Verified by: Name		
Date		

Form : 10. Geodatabase - TOA data (State Mosaic)

Data set name	img	Ex.:TOA0100KARF0405.IMG	
	xml	Ex.:TOA0100KARF0405.XML	
Mandatory fields (check whether parameters are filled)			Remarks
Project Code	yes/no		
Project Name	yes/no		
User Name	yes/no		
Product Name	yes/no		
Classification Team	yes/no		
State Name	yes/no		
Satellite-ID	yes/no		
Sensor-ID	yes/no		
Pixel Resolution	yes/no		
No of quadrants	yes/no		
Dates of Pass, Path and Rows	yes/no		
No. of Bands	yes/no		
Band Nos.	yes/no		
Layer Pixels	yes/no		
Layer Lines	yes/no		

Layer Format		yes/no	
Layer Data Type		yes/no	
Projection for image outputs	LCC	yes/no	
Datum for image products	WGS 84	yes/no	
Std. Parallel 1		yes/no	
Std. Parallel 2		yes/no	
Central Meridian		yes/no	
False Easting		yes/no	
False Northing		yes/no	
Corner Coordinates: TLLat TLLong LRLat LRLong		yes/no	
Check for well-formedness of metadata in xml format		yes/no	
Executed by: Name			
Date			
Verified by: Name			
Date			

Form : 11. Geodatabase – Classified data (State mosaic)

Data set name	img	Ex.:CLS0100KARF0405.IMG
	xml	Ex.:CLS0100KARF0405.XML
	Ref. xml	Ex.:TOA0100KARF0405.XML
Mandatory fields (check whether parameters are filled)		Remarks
Project Code	yes/no	
Project Name	yes/no	
User Name	yes/no	
Product Name	yes/no	
Classification Team	yes/no	
State Name	yes/no	
Season	yes/no	
Method of Classification	yes/no	
Data sets used	yes/no	
No. of training sets	yes/no	
Signature separability	yes/no	
Sampling scheme	yes/no	
Sample size	yes/no	
Size of sample site	yes/no	
Subplots	yes/no	
Overall Kappa accuracy	yes/no	
Individual classes Kappa accuracy	yes/no	
Edge matching	yes/no	
Executed by: Name		
Date		
Verified by: Name		
Date		

Form : 12. Geodatabase – Outputs (Softcopy)

Data set name	pdf	
Project Code	1216	
Project Name	<i>National level LU/LC Mapping using AWiFS</i>	
User Name	<i>NRR and DPD Geodatabase team, LU/LC-AWiFS Project</i>	
Geodatabase Team		
Theme Title		
Geographical Area		
Output Scale		
Output size	A0/A3	
Projection	LCC	
Datum	WGS 84	
Std. Parallel 1		
Std. Parallel 2		
Central Meridian		
False Easting		
False Northing		
Framework/Non-framework		
Corner Coordinates: LLLat LLLong URLat URLong		
Elements as per defined format	NRR formats	
Overall Thematic accuracy		
Output Symbology	As per Layer Legend	
Statistics summary		
Executed by: Name Date		
Verified by: Name Date		

Form : 13. Geodatabase – Outputs(Hardcopy)

Data set name	Hard Copy	
Project Code	1216	
Project Name	<i>National level LU/LC Mapping using AWiFS</i>	
User Name	<i>NRR and DPD Geodatabase team, LU/LC-AWiFS Project</i>	
Geodatabase Team		
Theme Title		
Geographical Area		
Output Scale		
Output size	A0/A3	
Projection	LCC	
Datum	WGS 84	
Std. Parallel 1		
Std. Parallel 2		
Central Meridian		
False Easting		
False Northing		
Framework/Non-framework		
Corner Coordinates: LLLat LLLong URLat URLong		
Elements as per defined format	NRR formats	
Overall Thematic accuracy		
Output Symbology	As per Layer Legend	
Statistics summary		
Executed by: Name Date		
Verified by: Name Date		

Form : 14. Quality evaluation

Ref No. -----

Project Title	<i>National level LU/LC Mapping using AWiFS</i>				
Project Code	1216				
Parameters	Prescribed	Claimed	Samples	Achieved	Remarks
A. Project Planning Project schedule Project reviews Project progress User feedback					
B. Image registration Image quality Cloud cover over study area Pixel / line drop out: Registration of images No. of GCPs RMS error Positional accuracy Mosaic Shift (X & Y)					
C. Image Classification Ground truth collection Dates and duration Samples Distribution Classification Accuracy Training areas separability Kappa Accuracy					

<p>D. Geodatabase Legend Format Identification Authorisation Data sets availability</p>					
<p>E. Geodatabase – Output Map components Aesthetics Symbology followed</p>					
<p>Quality evaluated by: Name designation, signature and date</p>					
<p>Evaluation Authorised by Name designation, signature and date</p>					