Chapter 1

Introduction

1.1	Overview	*3*
1.2	Background and motivation of study	*4*
1.3	Objective of the thesis	*5*
1.4	Scope of work	*5*
1.5	Overall research methodology	*6*
1.6	Novelties of the thesis	*7*
1.7	Organization of the thesis	*8*
1.8	Summary	*10*

1.1 Overview

Mining always leaves its footprint on the forest, wildlife, and people all around the world. The extraction of minerals resources is essential for the development of the society or the country. However, this may adversely affect the natural environment like plants and animals. Unplanned mining causes damage and deterioration of natural resources. Iron ore mining plays a significant role in socio-economic development, but on the other hand, such a supply can also harm the environment and forest ecology (Farmer, 1993). For example, transportation of minerals can lead to dust emissions and deposition at roadsides and on the leaves of trees, which lead to vegetation degradation. The plant may get affected by dust in many ways, either physically, chemically or biochemically. Dust deposition on leaves may affect the growth of the plant, it decreases the forest productivity, causes necrosis of leaves also as well as changes the community structure of the plants (Nagajyoti et al., 2010). Dust affects the diversity of plants and animals; also, it reduces the canopy density; as a result, the reflectance gets diminished (Garden, 1970). It may also be noted that the excessive dust decreases the water retention of the atmosphere as well as increases the temperature. The generation of dust is one of the significant impacts of mining and transportation of ore in the area. Forest roads are being used for transportation of minerals, which produce a vast amount of dust (Ghose, 2007). Though trucks with water are used for dust suppression on roads through sprinkling, it is not at all effective, especially during the hot season resulting in dust polluting the entire area. The vegetation along the whole length of the road is covered with dust, thereby affecting the growth and reducing palatability to whatever wildlife using the area.

Remote sensing plays an important role in different forest applications and combining it with other techniques can result in better qualitative-quantitative analysis. Remote sensing instruments can provide detailed information on the forest health condition and it have been used for decades to the spatial map of forest cover, health condition, and vegetation characteristics (Reed et al. 2009). The advances of hyperspectral remote sensing technology show the potential of monitoring the dynamics of the forest health at spatial and regional scale level (Thenkabail et al., 2014). This technology has provided more accurate information on forest biochemistry and biophysical properties of vegetation (Blackburn, 1998). Most of the work on forest biochemistry information testing due to the help of narrow banded (Hyperspectral) vegetation indices (Blackburn, 2006; Merzlyak et al., 1997).

Hyperspectral remote sensing is a very useful tool for forest health monitoring and it offers high accuracy as compared to multispectral data. It involves capturing of the reflected electromagnetic wave by an object in very narrow bands. Narrow bands divide the normally optical range between 0.3 to 2.5um. The forest tree species have a different level of textures at the different stage of his growth; therefore there is a variation in the reflected electromagnetic waves. Thus the satellite-based earth observation data can easily identify the tree health condition.

Mining activities often cause forest degradation, damage, and deterioration of biodiversity, as well as an ecological system. It results in the change in natural tree patterns and species biodiversity over the years. However, such changes are not yet well quantified, and its overall impacts on the future of the forest tree species are still not defined. This study mainly concentrates on the forest health monitoring and its risk prediction using hyperspectral satellite imagery for geo-environmental planning and management in hilltop mining areas.

1.2 Background and motivation of study

Iron is the second most abundant metallic element in the Earth's crust. The iron ore minerals are located in Saranda forest, West Singhbhum district of Jharkhand, India. This area is also known as Asia's largest Sal forest. There is a region with a vast area under forests, harbouring a variety of plants and animals. This area is mainly famous for the largest iron-ore mines, namely Gua, Meghahataburu Kiriburu and Chiria both governed by SAIL (Steel Authority of India). Most of the iron ore mines are in Saranda forests with a small portion in Chaibasa South and Kolhan Forest divisions. The working plan for the SFD (Saranda Forest Division) has listed 286 species of plants in this region (FSI). Mining is closely related to forestry and environmental issues. Mining activities in the iron ore belt of the Saranda forest of Jharkhand in the Karo and Koina river basin have very high potential to induce forest health problem. Also, it has the potential to disturb the ecological balance of this area.

One of the major impacts of mining and transportation of iron ore is generation of dust. The mining activities involve increased road network in the forest land for transportation of iron ore. Often this is associated with use of local forest roads beyond its carrying capacity. For example, it was observed that the road between Gua to Pecha (approximately 25 km), where 80 trucks with iron ore were seen plying, most of them were not covered and the roads not made wet through sprinkling (SAIL report). The increased number and network of roads, the number of vehicles plying and the infrastructure developed for mining and related activities lead to fragmentation of the habitat available to the wildlife.

However, the extraction of the mineral resources of the nation is given more priority for the needs of economic development. Mining activities of Saranda forest often lead to land degradation, deforestation, atmospheric pollution, pollution of the aquatic system, soil erosion from the overburden dumps and broken area. All these affect the forest ecosystem.

1.3 Objective of the thesis

This study explored the potential of Hyperspectral satellite Imagery for Forest Health Monitoring and Risk Prediction in hilltop-mining affected forest areas. The objectives are include:

1. Evaluation of the potential of hyperspectral satellite imagery and spectral signature of plants as a tool for forest health assessment.
2. Development of hyperspectral library of plant species for identification and diversity estimation.
3. Development of a hyperspectral satellite imagery based new methodology for foliar dust estimation and its field measurement for validation.
4. Assessment and prediction of Forest health risk (FHR) for effective planning and management of forest in mining-affected area.

1.4 Scope of works

In order to meet the above objectives, the scope of works includes:

a) Assessment of forest health using Hyperion and Landsat OLI data.
b) Forest health data acquisition with field Spectroradiometer and PCE instrument.
c) Selection of the most effective model between different VIs model and SVM, SAM algorithms.
d) Comparison between narrow banded (Hyperion) and broadband (Landsat OLI) data for forest health assessment.

e) Determination of relationship between forest health and foliar dust concentration, as well as with distance from mines.
f) Identification of tree species and assessment of its diversity using hyperspectral data.
g) Selection of the most effective algorithms for tree species classification and mapping.
h) Estimation of the tree species diversity based on Shannon Index using narrow banded VIs.
i) Comparison between Hyperion imagery derived from Shannon index and field measured Shannon index.
j) Determination of impact of distance from mines on the species diversity and foliar dust concentration.
k) Development of a new method for foliar dust estimation using hyperspectral satellite imagery and experimentally determined spectral data of dust affected leaves of forest tree.
l) Comparison of the result of narrow band Hyperion data with broadband Landsat data for relative accuracy of foliar dust estimation.
m) Determination of the foliar dust concentration as a function of the distance from the mines.
n) Assessment and prediction of the risk to the forest health (FHR) of mining-affected forest area.
o) A comprehensive study involving a total of twenty eight parameters (twenty-two are from past time domain and six from future time domain) for FHR assessment and prediction.
p) Multi-criterion based AHP model in a GIS framework is used in this study.
q) Sensitivity analysis identifies the dominant factor that affects the forest health risk.

1.5 Overall research methodology

Four leading open cast mining (Kiriburu, Meghahatuburu, Gua, and Chiria) of India is situated in Saranda forest. The problem induced due to mining and its activity is the critical problem of the Saranda forest, Jharkhand, India. To cater the growing iron ore needs of the country, mining activities is also growing in these regions, which consequences to forest health problems.

To conduct the study efficiently and comprehensively, data were collected from various sources. All data were pre-processed and analyzed with proper scientific methods before feeding in Advanced Remote Sensing and GIS tools. In this study, a methodology is proposed for forest health assessment and its risk prediction based on hyperspectral satellite imagery and field-based tree spectral data for effective geo-environmental planning and management in hilltop mining areas. The overall research methodology is shown in Figure 1.1.

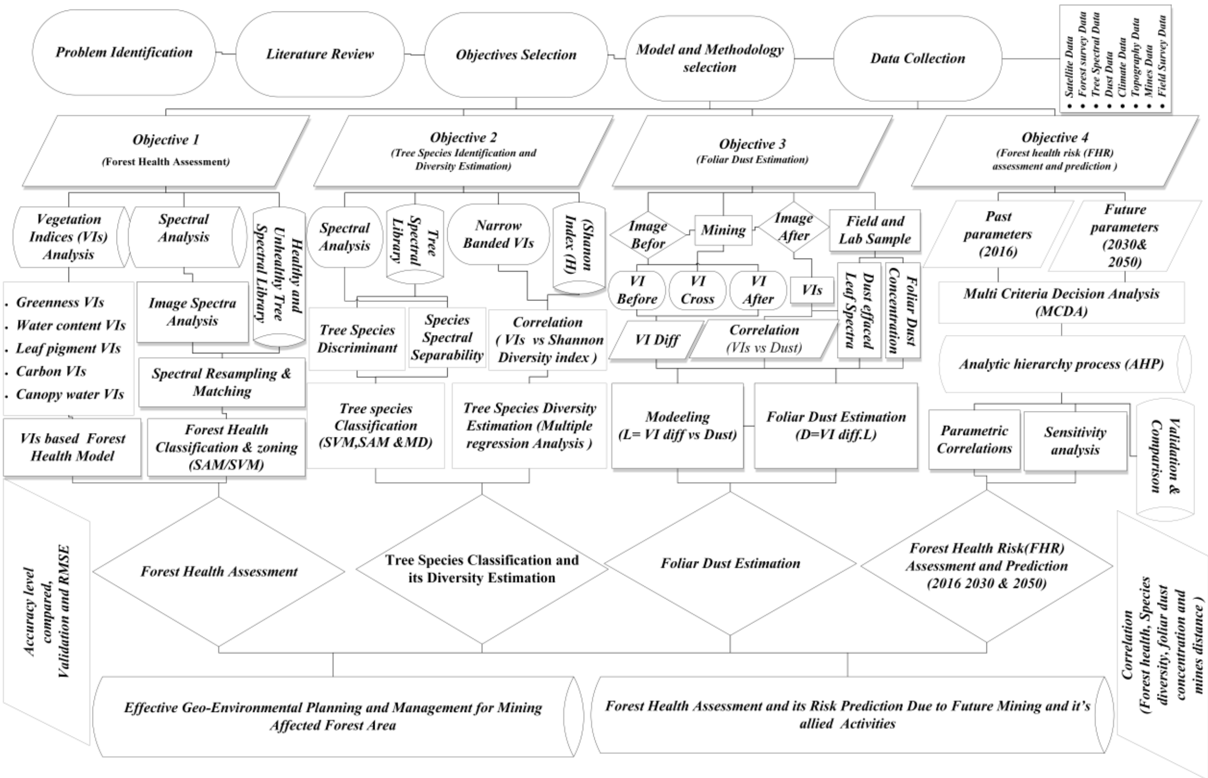

Figure 1.1: Overall flow chart of research methodology

1.6 Novelties of the thesis

The study area is an interior part of the Saranda forest, Jharkhand. This area has two large iron ore mines (Kiriburu and Meghahataburu) apart from several small pockets of mines. There is no scientific work related to forest health assessment, tree species identification, plant diversity estimation, foliar dust estimation, forest health risk (FHR) assessment, and prediction have been conducted till date. All the work included in this thesis will be the first of its kind for Saranda forest, which could make the area noticeable to local administration for future work related to forest planning and management.

1. This study provides forest health assessment in the mining-affected forest area. The work portrays the hyperspectral satellite imagery (Hyperion), and tree spectra data that have been used for assessment of forest health. Also, narrow banded VIs model

has been used for the assessment and validated with tree spectral data obtained from Spectroradiometric field survey.

2. The study includes tree species identification and its diversity estimation' based on discriminant analysis using hyperspectral satellite imagery and field survey data in the hilltop mining area. Also, the relationship between species diversity and foliar dust concentration as a function of distance from mines is established for the area.

3. This study carried out foliar dust estimation with the help of hyperspectral satellite imagery and field-based foliar dust contents. It also compared the outcome of hyperspectral and multispectral data to find the reliability of the VI_{diff} based foliar dust model.

4. Forest health risk (FHR) prediction in mining-affected forest using AHP model based on the multi-criterion analysis in a GIS framework have also been included. A total of twenty-eight parameters (of which twenty-two are from present time domain and six of future) have been used in this study.

1.7 Organization of the thesis

This thesis consists of seven main chapters with a conclusion and summary chapter, along with a bibliography section. Chapter 1 is introduction, and chapter 2 deals with the literature review. Chapter 3 provides a brief description of the study area. Chapters 4 to 7 describe the entire works (objectives) done in the thesis. The material, methodology, analysis, results, discussion, and summary is objective wise presented in each chapter. Chapter 8 reports the conclusion, summary, limitation, and future scope of the work.

Chapter-1 Provides the general introduction of the thesis as well as shows the background of the study, objectives, the scope of work, overall research methodology, novelties and, organization (chapters) of the thesis.

Chapter-2 Demonstrates literature review under the heads of worldwide forest health, tree species, plant diversity, foliar dust, and forest health risk (FHR) for mining-affected forest area. It also discuss the application of multispectral, hyperspectral remote sensing (RS) and geographical information system (GIS) based assessment of forest health, tree species classification, plant diversity measurement, foliar dust estimation, forest health risk (FHR) assessment, and prediction.

Chapter-3 Describes the soil, geology, geomorphology, LULC, climate, altitude, slope, forest type, tree species, river, drainage pattern, watershed, transportation, settlement, population, natural resources, agriculture, and livelihood of the study area.

Chapter-4 Deals with forest health assessment based on hyperspectral and multispectral satellite imagery and field measurement based tree spectral data in the mining-affected forest region. Narrow banded vegetation indices (VIs) based forest health model have been used in this work. Also, SAM and SVM based algorithms were used for forest health classification based on ground tree spectral data. Comparison of forest health classification accuracy between narrow banded (Hyperion) and broadband (Landsat OLI) data based on healthy and unhealthy tree spectral data from field survey have also been performed. Correlation with distance from mines as a function of forest health and foliar dust concentration were also included.

Chapter-5 Reports tree species identification and estimation of plant diversity using hyperspectral satellite imagery and field survey data. Wilk's lambda (L) test have been used for waveband selection through discrimination analysis of tree species. Tree species wavelength locations were selected for spectral separability analysis using the JM (Jeffries Matusita) distance method. The supervised classification (SVM, SAM, and MD) methods were applied for tree species classification based on ground tree spectral data. Also, the compared the accuracy level of tree species between narrow banded and broadband satellite data. Selections of narrow banded VIs were used for tree species diversity estimation based on the Shannon diversity index.

Chapter-6 Describes the foliar dust estimation using Hyperion (narrow-bands) and Landsat (broad-bands) images, with the aid of eight different vegetation indices (VIs) and field-based laboratory spectral data analysis. The healthy and dust contaminated areas were detected by vegetation combination analysis using narrow banded VIs. The study shows the relationship between dust affected leaf spectra and foliar dust concentration. Vegetation different (VI_{diff}) based foliar dust model were used for the estimation and mapping. Hyperspectral image and ground-based spectra data are integrated into the foliar dust model. Comparison of narrow-band Hyperion data with broadband Landsat data were performed in the foliar dust estimation.

Chapter-7 Provides the forest health risk (FHR) assessment and prediction using AHP based multi-criteria analysis in a GIS framework. We had considered a total of twenty-eight parameters, including climate, natural or geomorphology, forestry, topography, environmental, and anthropogenic variables for FHR study. Of which, six parameters were derived from the future time frame (2030 &2050). The study shows the sensitivity analysis of FHR related parameters and identifies the parameter that greatly affects the FHR. Also, correlation methods were used to establish the relationship between forest health risk index (FHRI) and the most sensitive parameters. Spectroradiometric field survey data of tree spectra were used for validation of the 2016 year results. Comparision of the prediction results (Present, and predictied) were performed by ROC curve.

Chapter-8 reports the significant finding of preceding chapters, and the final conclusion and summary are drawn. The limitations of this study are also indicated. Suggestions for the future scope of study are also pointed out.

1.8 Summary

This chapter shows the general introduction of the study. In the study area, increasing mining and anthropogenic activities within and near the forest lands are causing a threat to forest health. All these necessitated the monitoring of forest health in surrounding mining areas.