CHAPTER ONE

INTRODUCTION TO THE STUDY AREA
1.1 Introduction

Land degradation has been one of the most serious ecological problems in the world, but unfortunately there does not exist any universally applicable definition of degraded land. Often wasteland and degraded land are used as synonyms (Reddy, 2003). Usually it is regarded as the alteration and spoiling of land, rendering it worthless for any useful purpose (IBM, 2000). National Remote Sensing Agency (NRSA) in consultation with the Planning Commission and other concerned Departments/Agencies describes it as 'land which can be brought under vegetative cover with reasonable effort, and which is currently under-utilised and land which is deteriorating for lack of appropriate water and soil management or on account of natural causes. Wasteland can result from inherent/imposed disabilities such as by location, environment, chemical and physical properties of the soil or financial or management constraints’ (NRSA, 1991). Thus land degradation is the loss of utility or potential utility of land through the reduction of or damage to physical, socio-cultural or economic features, and/or reduction of diversity of the ecosystem and behind it there may be a single cause or complex mix of causes like biogeophysical ('natural’), socio-economic('anthropogenic’) or it is quite possible that cause(s) may be indirect, cumulative and difficult to identify. Degraded land which may be unutilised, partially utilised or mismanaged land may fall under state occupation, private occupation or notified forest areas. NRSA (1986) has accepted culturable wasteland and unculturable wasteland as two variants of Level-I degraded land. Further under Level-II of culturable wastelands, it has identified mining activities as one of important factor causing land degradation. Ghosh (1999) agrees that land degradation in unplanned mining and related activities are of cyclic nature (figure-I.1). Greenery loss from an area makes it barren. Any barren land is prone to direct ill effect of sunlight, rain, wind etc. and soil erosion. This process leads into more siltation, drying of surface water bodies and decreased water potential of land. This favours conditions suitable for drought and desertification. Mining activities through direct vegetation cutting, excavation, overburden dumping, mine water pumping etc. accelerates this cycle in many respects. It is interesting to note here that actual mining area covers only about 0.04 per cent of the country’s geographical area, but the ill impact of mining on land and
land use spreads up to many times the area actually disturbed by mining (Sharma, 1982). Further, among different types of mining activities, researchers all over the world have accepted coal mining and associated activities as one of the most potent factor which is directly or indirectly associated with land degradation in the area concerned.

1.2 Land Degradation in Coal Mining Areas

Scientists are working hard to find new land on Mars or Moon, but till now there is only earth to live. Land is the solid cover of this earth, thus it is a finite resource. Utility and requirement of land to human being cannot be questioned, and is further supported by the slogan ‘God made the land for the people’ (Ambrose, 1977). This very important finite natural resource land becomes derelict if it is put to improper use (Ghosh, 2002). Unplanned coal mining is one of such activity which may put this one of the most precious resource with human at great risk.

Since very long time man is mining coal and treating it as one of important means to meet his energy requirements. Coal mining is the extraction of the coal by the simplest possible method, avoiding other layers that sandwich the coal seams such as shale, sandstone, limestone and other country rocks (Leong and Morgan, 1982). Coal is a black or brown rock, consisting mainly of carbon, which is formed by the compressed vegetative remains of past ages. In swampy deltaic areas with a hot and wet climate, luxuriant new forest grew, died and deposited as compressed peaty layers on the ground. Under heat and pressure, generated by increasing weights of subsequently deposited sediments and earth movements and contortions; the vegetative mass slowly changes into coal seams. Due to these complexities the carbon content of various types of coal differs considerably from peat and lignite with very low carbon content to bituminous with 40-80 per cent carbon, anthracite with about 95 per cent of carbon and graphite with 99 per cent of carbon content. Due to the same reason the moisture and volatile matter content also vary in different types of coal. Thus extractions of various types of coal are associated with various amounts of impurities. Not only it, coal mining
methods are of various kinds like striping or open-cast mining, drift or adit mining, shaft mining etc. and thus producing various kinds of degradation to the area. Besides, coal has multiple commercial uses, from domestic fuel to metallurgical coke, chemical industry, thermal power plant etc. Since coal is a weight loosing commercial input, so most of its concentration take place near the mining area. All these activities are associated with various type of treatment to the mined coal and thus producing various type and amount of impurities.

Coal mining is a measure habitat transforming activity which has a number of detrimental environmental consequences, namely soil erosion, acid-mine drainage and increased sediment load as a result of abandoned and un-reclaimed mined lands (Parks et al., 1987). Besides considerable amount of solid waste piled in the form of huge overburden dumps, destruction and degradation of forest and agricultural lands and
discharge of effluents from mines into nearby water-bodies are some of the other associated problems that have adverse environmental impact (Kandrika and Dwivedi, 2003). In fact the impact of mining on land and land-use starts at the time of land acquisition and continues up to use of the mined-out product (Ghosh, 2002). Following are the some important aspects of land degradation in any coal mining areas (Based on Ghosh, 1999 & 2002 with certain modifications):

**Land Acquisition and Vacating**

Immediately after acquisition of a piece of land for mining, the pre-mining uses of the acquired lands need shifting. This may need construction of houses and other facilities for the displaced people, which, in turn, need a new land, which may cause damage to greenery and require excavation of land. Further, the rehabilitated people try to grow their food at the new site and hence have cultivation on any small piece of available land. All these increases soil erosion potential of the region which may gradually fills up the surface water bodies through siltation. These phenomena have two way effects on agriculture of the area. Direct erosion reduces fertility of the soil and reduced water holding capacity of different water bodies of the area reduces irrigation potential of the area. With reduced irrigation potential the cropping intensity of the area decreases. Reduced cropping intensity means people now need more land to raise same level of food output and also the land which earlier used to be occupied by different crops for longer part of the year, will now remain exposed to scorching sun and wind. This will further dry the land and wind erosion increases. Also with loosen soil materials, the surface runoff in next monsoon will carry most of the valuable soil particles with them. High surface runoff causes decrease in infiltration of rainwater and also due to accumulation of excess clay and silt at the bottom of different surface water bodies, infiltration from their bottom decreases. Over the years these two phenomena in association of partial capillary water loss in dry season, causes depletion of groundwater. The cumulative effect of all these features is that development and growth of vegetation further restricted in the area to pave the way towards increased land degradation and lastly desertification.
Clearing the Vegetation Cover

Forests act as a climatic stabiliser, inhibit flooding and sedimentation. Decrease in forest increases temperature and disturbs the process that results rain. Tree roots provide extra shear strength to the soil to aid in resisting gravity movement and surface erosion. The forest canopy acts to dampen raindrop impacts, and the trees ground litter further reduces erosion potential. The decaying vegetal matter enriches the nutrients in the topsoil horizon and increases permeability to allow infiltration of water through it. Thus direct run-off is minimised and sheet flooding is prevented. But deforestation causes increased soil erosion, increased down slope sedimentation and flooding, upsetting the hydrological regime, destruction of wildlife habitats and reduction of aesthetic qualities. In this regard Coates (1981) observes deforestation lowers the minimum temperature by $1^\circ-7^\circ F$ in all seasons and to increase the maximum temperature by $1^\circ-3^\circ F$ in cold season. Humidity decreased by 2-25 per cent and rainfall reduction by 1-10 per cent has also been documented in degraded areas. In tropical countries like India this problem is further acute. Tropical soils are surprisingly fragile and vulnerable to ruination. Nutrients in tropical soils occur mostly in the plants; the soil offers only the mechanical support for growth. When the canopy protection is demolished, soil temperature is raised to destructive proportions which hasten biological and chemical deterioration of the remaining organic matter. Heavy rains leach away the remaining nutrients and remove these by surface erosion of the productive upper soil horizon causing land degradation. Unfortunately nearly all mining needs require clearing of the acquired land which in most cases need removing its green cover or even deforestation in some cases, which invites land degradation.

Excavation

Movement of the earth’s crust such as folding, faulting and vulcanicity often complicates the structural position of coal seams making mining both difficult and expensive (Leong and Morgan, 1982). Further they observed, coal mining methods are very much influenced by such factors as the nature of coal-occurrences; the thickness of the coal seams; the depth of the seams; the amount of overburden and nature of the overburden strata; the degree of distortion in the coal seams; the type of the coal and the
mode of operation. Impact of mining on land, due to excavation depends upon the type of mining. Broadly there are two types of mining, surface or open cast (OC) mining and underground (UG) mining, depending upon the depth of the deposits to be mined (plate-1.1 and 1.2). Further, depending upon the terrain condition there are broadly two types OC mining, ‘area strip mining’ and ‘contour strip mining’. Contour strip mining refers to the method which exploits the minerals by excavating along the contour lines on hill slopes or mountain while area strip mining is the method applied on rather flattish terrains. Similarly, UG mining operations can be of various types like drift or adit; slope; shaft mining etc., depending upon the characteristics of the deposit especially its mode of occurrence. Each of these mining due to its unique way of excavation affects the lands of the mining area differently-

(i) Area Strip Mining

In outline, the method involves stripping away the overburden (OB) (if present) and to recover the mineable by use of bulldozers, scrapers or by manual operations. This obviously forms great scars on land at the site of excavation and large piles of OB materials where the waste is dumped. This results into land degradation and land pollution at the excavation sites and also at the dumping sites.

Excavation in any OC mining degrades the land quality as it loses its soil cover and gets lowered from its original topographic height. Soil profile in the region gets disturbed and hence the soil quality, its chemical and physical character, behaviour with water, none remains as it was in original condition, because huge mass of land is excavated from its original site and placed at new site. The quarries generated by excavation if left unreclaimed, that amount of land become useless.

If the depth of excavation is such that it damages the upper part of the aquifer underground, water flows into the excavation site continuously from the remaining part of the aquifer. This water is continuously pumped out to facilitate mining and thus causing regional groundwater depletion and decrease in irrigation potential. In some other cases where the quarry is deep enough to excavate out the total aquifer in the region it not only brings aforesaid problems
Plate: 1.1 Open cast quarry in the vicinity of settlement in the Jharia Coalfield.

Plate: 1.2 Open cast quarry and associated OBD, water accumulation at depression and use of heavy machinery.
but also a persistent problem. Even when the quarry is backfilled for the purpose of physical reclamation, it is filled with materials that are too loose to represent the impermeable layer that was originally existed at the base of the aquifer. Thus the aquifer is never regenerated. This creates a situation which goes against sustainable greenery growth over these mine degraded lands, even after the so-called biological reclamation.

(ii) Contour Strip Mining

Such mining exposes fresh surfaces on sloping land and hence makes these highly prone to rain wash, weathering and erosion, which results siltation in the surrounding water bodies. Such weathering and erosion may even cause water pollution if unwanted materials get mixed with it. Besides, occasional rolling of unused mined out materials in association with above phenomena may create severe land degradation in the area.

(iii) Underground Mining

Underground mining activities are generally less polluting in comparison to open cast mining activities. The most important land degradation problem associated with underground mining activities is land subsidence which has been dealt separately.

*Overburden Dump (OBD)*

Overburdens are the earth materials between the surface and coal seams (*plate-1.2*). They need to be entirely removed in order to reach the coal seams directly. Firstly, it causes loss of vegetation/ agricultural land in the areas that is the area from where it is excavated and the area where it is deposited. Soil profile in such OBD is reversed. Thus more nutrient rich soils are deposited at the bottom whereas nutrient deficient soil at the top. As a result of it any fresh vegetation development on these dumps are difficult. As also these dumps generally have higher slope in comparison to the natural topography of the surroundings. This break in slope area is not only prone to erosion but at times may cause small landslides also. Further, in inverted soil profile the bottom soil with rich organic nitrogen under anaerobic condition generates ammonium ion which comes under aerobic condition during reclamation. Under aerobic condition ammonia oxidised
to nitrate which lost to water and atmosphere. This loss of nitrate not only causes
depletion of valuable soil but also pollution to drainage water. Thus there are several
changes in the physical, chemical and microbiological properties of soil as a result of
storage (Ghose and Kundu, 2003). Mine spoils pose adverse conditions for soil microbe
and plant growth, due to its low organic matter and other essential nutrients and
unfavourable soil chemistry, poor structure- either coarse or compact, and high isolation
from vegetation (Meyer, 1973; Harthill and Mckell, 1979). Poor microbial population
inhibits nutrients transformation, the establishment of the plant growth and the process
of ecological succession (Singh et al, 1996). Thus their natural recovery may be very
slow and take several years.

**Land Subsidence**

Subsidence is defined as any movement at any place in the earth’s crust or on the
surface due to any natural and/or manmade activities (Saxena et. al., 1989). According to
Ghosh (2002) such situation may develop due to many causes, natural or manmade. Some important causes of subsidence in coal mining areas are-

- Underground excavation for mining
- Open excavation for mining
- Pumping and withdrawal of liquid from underground mines
- Subsurface fire in coal seams

Land subsidence in underground mining areas is an often-heard phenomenon which
usually occurs due to not proper feeling of voids created in underground coal
excavation. It causes disturbance in superincumbent strata and the upper land subsides
for the want of any support.

In open cast mining subsidence, in technical sense, is caused due to slope failures
(Ghosh, 2002). If such situation occurs in any area strip type mining where excavation
takes place below the regional contours, it will cause a limited damage to the land
surrounding excavation. But if such subsidence takes place in contour strip type mining
areas, it will disturb the regional contours, land-use and land-cover of the region along
with altering physical and chemical characteristics of the soil in the area.
Often pumping of water from aquifers in coal mining areas are required if an excavation beheads any aquifer or if water is required for human and other coal related consumption. The aquifers hold water at a certain hydrostatic head and the stresses are in the state of equilibrium in natural condition. As soon as pumping of water is started from the aquifer, a drawdown zone develops around the pumping site causing reduction of hydrostatic pressure around. As a result of this the stress equilibrium is disturbed. If such situation retains years after years the equilibrium is regenerated by some grain to grain rearrangement to remove the fine pores which were providing spaces in the strata produced by removal of water due to lowering of water table, thus to compensate the loss of hydrostatic pressure. Under such circumstances the aquifers get compacted under the stress due to the load of superincumbent strata. The compaction manifests on the surface in the form of land subsidence. Once the aquifer attains such situation it cannot be recharged by natural process because the porosity to hold the water had already been lost through compaction (Ghosh, 2002).

Subsurface coal fire which is not uncommon in many coal mining areas after a long period causes substantial loss to coal seams. It may directly create a void and may also alter the physical and chemical prosperities of super incumbent strata to ultimately unstablise and subside it.

As far as land subsidence is concerned, it is not necessary that only one factor is responsible for it, at times different factors work in association to cause subsidence of land. Sometime tremors, either due to blasting or earthquakes also trigger this event. Whatever may be the cause and amount of subsidence, it disfigures topography of the region and alters the drainage conditions, runoff pattern, hence transportation pattern of soil particles and hence the water regime. The quality (physical and chemical) of the land obviously gets disturbed (Ghosh, 2002).

Surface and Sub-surface Fire

All over the world coal fire are very common phenomena in coal mining areas. Coal is a combustible material which reacts with atmospheric oxygen even at ambient temperature to give CO and/or CO$_2$. 

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Plate: 1.3 A scene of coal fire in the Jharia Coalfield.

Plate: 1.4 Coal waste depositions at dumping site by heavy vehicle in the Jharia Coalfield.
This reaction is exothermic. If heat is allowed to accumulate, this reaction further increases and when ignition temperature is attained it starts burning instantly (plate-1.3). This process is called a spontaneous burning. Atmospheric oxygen reaches to coal seams easily if it is exposed at the surface or due to presence of cracks and voids. Fire may also generated due to anthropogenic negligence like heat generated during blasting activities, frictional sparks, electrical short-circuiting, dumping of hot ash, smoking by miners, etc. Here it must be noted that thermal capacity of coal is inversely proportional to its ash content, that is, greater the ash content lesser is its thermal efficiency and vice-versa (IGNOU, 2006). It means better the quality of coal higher be the coal fire risk. In any case coal fire causes direct loss to valuable coal, change in surface soil properties, vegetation/agricultural land loss, air pollution, land subsidence, higher mining risks, etc.

**Pumping out of Mine Water and Acid Mine Drainage (AMD)**

Usually in all coal mining areas, at places coal excavation may encounter with the aquifer of the area. Thus, whether damaging partially or fully aquifer in such an excavation, pumping of water become necessary for further excavation. Such pumping of water may create problem. As aquifer looses water so groundwater depletion takes place. This pumped water is usually spreaded at nearby surface thus increasing surface evaporation. With this disturbed local hydrological regime the water potential of the area decreases. Singer and Stumm (1970) explains if the minerals also have iron pyrites, then it reacts with the aquifer water to give sulfuric acid in the following ways -

\[
\begin{align*}
\text{FeS}_2 + 3.5 \text{O}_2 + \text{H}_2\text{O} & \rightarrow \text{Fe}^{2+} + 2 \text{SO}_4^{2-} + 2\text{H}^+
\text{Fe}^{2+} + 0.25 \text{O}_2 + \text{H}^+ & \rightarrow \text{Fe}^{3+} + 0.5 \text{H}_2\text{O}
\text{Fe}^{3+} + 3 \text{H}_2\text{O} & \rightarrow \text{Fe(OH)}_3 + 3\text{H}^+
\text{FeS}_2 + 14 \text{Fe}^{3+} + 8\text{H}_2\text{O} & \rightarrow 15\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 16\text{H}^+
\end{align*}
\]

This process is called AMD. This acidified water pollutes groundwater and making it unfit for irrigational purpose. If it is directly pumped to the nearby area it produces harmful effect on the vegetation of the area by altering the soil chemistry. Occasionally acidic water also generated after rainfall from OBD containing iron pyrites. All these causes increase in the acidity of soil, decay of materials which are active even at low acidity and decrease in vegetation coverage.
**Dust and other Waste Materials**

Different uses of coal require its handling and intensive use of transporting vehicles (*plate-1.4*). ‘Excavation is followed by haulage, storage and transportation of excavated materials. All these activities spread dust and thus create air pollution, water pollution, and damage to greenery in the surroundings and hence land degradation due to spreading of the fine rock and mineral particles’ (Ghosh, 2002). Coals have multiple uses and due to its bulky nature most of such activities are usually concentrated in mining areas. Most of such treatments produce some byproducts like ash from thermal power plant, which, if not used-up, form a huge dump of waste creating land degradation. Oil and grease as waste material are generated in different workshop. Harmful chemical residues are also generated in blasting activities. In nutshell all these activities together cause severe damage to the nearby land.

Thus broadly there are two types of coal mining around the world, open cast and underground. World over open cast coal mining is regarded to have more adverse impact on land than underground mining. But with the improved technological managements, open cast coal mining are being increasingly used for its cost effectiveness, less human danger involved and higher coal productivity. Thus open cast coal mining, which is indispensable for the increasing fossil fuel demands, is always liable to bring large scale changes in the natural topography of an area (Ghosh, 1989; Rathore and Wright, 1993; Das and Pathak, 2005). No doubt underground coal mining has considerably less impact than open cast mining on land, but it causes enough damage through subsidence which further inflicts severe damage to valuable engineering structures such as highways, railways, buildings, bridges, etc. Thus, in both the cases whether open cast or underground, coal mining areas are very much prone to land degradation due to clearance of vegetative cover for mining, large scale excavation, stock piling of over-burden dump, hindrance in natural drainage, triggered soil erosion, spread of coal waste into nearby cultivable land, loss of valuable top-soils, land subsidence, coal seams fire associated problem, undermine blast, dust generation during coal transportation, etc.

The problems of land degradation become more complex and serious if we compare it with other component of environment. There are four broad component of
environment - the lithosphere, the biosphere, the hydrosphere and the atmosphere. In our nature these four are in juxtaposition in a very balanced manner. Thus if we create imbalance in one component it will adversely affect the other components and thus the final sufferer will be the human only.

1.3 Overview of the Existing Literatures

The occurrence and development of wastelands or degraded lands is a universal phenomenon, however their magnitude and severity differ from place to place depending upon the type and intensity of activity (Narayan et al., 1989). They also observed that among different land degrading activities, coal mining and allied activities are one of the most important activities associated with it. Further, they supported the use of remote sensing and GIS in such land degradation study.

In her research paper on Jharia Coalfield Ghosh (1991) observed that the coalfield experienced extensive mining since 1925 without taking into account any environmental concerns. Further since nationalisation of coal some attention were given to planned mining in the area, but a lot remain left to be done on actual ground. The paper discusses type of land degradation in the coalfield, their causes, extent and possible remedial strategy that need to be followed.

Jeyaram et al. (1993) have made extensive study on the environmental aspects of mining activities using remote sensing data. They found that mining is one of the industries which have relevance to economic development of any nation, but it is also the one which contributes most to environmental degradation of the area concerned. They observed that mining activities are often associated with adverse effect on other resources like soil, forest, crop land, grazing land etc. which can be estimated in degree and extent using temporal satellite data.

In their study of environmental impact of surface coal mining Rathore and Wright (1993) observed that mining in general, and coal mining in particular is one among many such activities that can produce significant environmental impacts. They identified some of the problems in such areas like increased erosion and gullying, acid
mine drainage, overburden dump, destruction and degradation of forest and agricultural land etc. Further, they appreciated the use of satellite data in all such study due to its high repetition and synoptic coverage.

Majumder and Sarkar (1994) observed that coalfield witnesses a complete transformation of both physical and cultural environment due to mining and related activities over the period. As a result of it, not only valuable top soil and forest, etc. are lost directly but also due to change in drainage, soil erosion increases in the area.

Mansor et al. (1994) in their study of underground coal fires in the Jharia Coalfield concluded that self-combustion due to incipient heating, is one of the many problems associated with coal mining. These can be detrimental to the production and overall quality of the coal and can constitute a major hazard to the miners. They observed that satellite data like AVHRR and TM are very useful in such study.

‘Coal-fires are a ubiquitous problem in coal mines world over’, say Prakash et al. (1995). In their study of the Jharia Coalfield they observed that coal-fires not only burn out prime energy resource, but also lead to atmospheric pollution and render mining of coal hazardous.

Saraf et al. (1995) in their study of the Jharia Coalfield observed that coal-fires are not only due to natural reasons but human errors are also there. Spontaneous combustion which is a major cause of coal-fire takes place whenever coal seam comes in contact with oxygen in the air through cracks, fractures, vents, etc. Negligent act on the part of mine workers and also spread of fires from refuse dump and abandoned mines may cause fire in working coal mines. Further, besides consuming valuable coal and danger to mine and mine machinery, coal-fires may also held responsible for land subsidence at many places.

While studying shelf-life of stock-piled topsoil in an opencast coal mine, Kundu and Ghose (1997) observed that topsoil are very valuable for reclamation of abandoned mines. Generally in normal conditions, after five years or so the topsoil loses its micronutrients and thus become biologically sterile. Unfortunately, replacement of soil in mining areas takes longer time and so topsoil need to be managed very carefully otherwise a widespread land degradation may result.
Singh et al. (1997) in their remote sensing study of impact of coal mining and thermal power plant, found that such activities on large scale deteriorates the ecosystem as a whole. Increase in built-up area, decrease in forest and agricultural area, increase in wasteland area are the some of the common features associated with coal mining and allied activities.

AEPG (1988) had been given the task to prepare an 'Advance Environmental Management Plan' for the Jharia Coalfield. They made a widespread observations including physiographical and socio-economic characteristics of the area, future demand of coal, effect of coal mining on environment and based on all these studies they suggested plan for future development of the Jharia Coalfield.

Gupta and Prakash (1998) found more than seventy major coal-fires in the Jharia Coalfield including both surface and sub-surface coal-fires. Here, they observed, subsurface coal-fires are more wide-spread in comparison to the surface coal-fires. Further, it has caused loss to precious coal resources, damage to natural land and anthropogenic structures, and poses danger to human beings. Also due to difficult accessibility of fire areas its direct study is difficult and remote sensing is very valuable in any such estimation.

Considering the complex history of the Jharia Coalfield, its land-use patterns were deeply investigated by Prakash and Gupta (1998) using remote sensing data. In their time series study of different land-use, they found a significant change in vegetation, fire, opencast coal mining, overburden dump, subsidence, settlement, transport network and barren wasteland area.

Schmidt and Glaesser (1998) observed changes and degradation of landscape in mining areas are fundamental environmental problem. The area may witness problems of erosion, gulllying, drainage of acid water, dump materials, oligotrophic properties of nearby lakes etc. It is often responsible for change in natural morphological situation and the landscape dramatically.

Tripathy et al. (1998) have made a soil quality analysis in the Jharia Coalfield by categorising land into three categories viz. non-fire, intermediate fire and fire zones. They observed that soil quality in fire areas have relatively low pH, moisture content,
organic carbon, micro-nutrients and high conductivity in contrast to non-fire and intermediate fire zones.

Ghosh (1999) has made a detail study of land-use pattern in the Jharia Coalfield. The author observes that land degradation begins rightly from the acquisition of land for mining and rehabilitation of people to other areas. The author also observed that continuously increasing mining and allied activities has resulted into widespread land degradation and overall land-use changes. The author also suggested land-use management strategy for the area.

'Mining is essentially a destructive development activity, where ecology suffers at the altar of economy', says Sinha et al. (2000). Further, often underground geological resources are superimposed by biological resources and hence mining operations necessarily involve deforestation, habitat destruction, biodiversity erosion etc. Its extraction and processing also lead to widespread environmental pollution and land degradation.

CPCB (2000) observes that coal has acquired dubious distinction of being dirtiest one among different fossil fuels due to the environmental damage and pollution problems caused during its mining, processing, end use and wastes of coal. Land subsidence in underground mines, ugly scars of land in abandoned open cast mines, emission of fly ash during combustion of coal and huge quantity of ash generated from boilers of coal based power plants are among the host of problems associated with handling and use of coal.

In his study of topsoil management for reclamation coal mining areas, Ghose (2001) observed opencast mining poses higher potential danger for land degradation in comparison to underground mining activities. However irrespective of the type of mining, land degradation is inseparably connected with it. The area may witness loss of vegetation, increased in soil erosion, huge overburden dump and voids and even sometimes landslides.

'This very important finite natural resource land becomes derelict if it is put to improper use' says Ghosh (2002). The author believed despite having a forest policy since the end of 19th century, the degradations of vegetation in mining areas are
widespread. The author has discussed why and how different type of land degradation take place in mining areas and how these problems can be effectively tackled.

IBM (2000) found that mining lead into large scale removal of earth materials which directly causes severe damage to the land. Often handling of such amount of earth materials generates dust which finally settles in nearby areas and thus further degrading the surrounding areas. They also say, the degree of damage is a function of topography of the area, the depth of mineral, the mining method applied and rainfall intensity and wind velocity and duration.

Singh (2003) has not only given the historical account of mining in the Jharia Coalfield but also analysed different problems associated with it. The author considers Jharia as one of the most important coalfield of the nation but it has certain problems which need to be addressed if we want to fully exploit the mineral of the area. He has suggested the way by which coal fire, subsidence etc can be effectively tackled.

Krishnamurthy (2004) observed that mining results into severe damage to land, air, water and vegetation. However, impact on environment largely depends on method of mining adopted, the geo-mining conditions of the locale and the size and duration of the mining operation. He further accepted that the crucial issue is not to reduce coal exploitation since demand of energy is rapidly rising, but to minimize the adverse impact on environment through proper management.

Thus in most of the studies concerning mining in general and coal mining in particular, accepted coal mining and allied activities as one of the most important factor causing severe land degradation. With the increased dependency on coal as a major source of energy need of the nation, its mining will further accelerate in future and with it the threat to land degradation.

1.4 Study Area
1.4.1 Locational Settings

The Jharia Coalfield in the Damodar Valley is the most important coalfield in the country both in regard to its potentiality and its development (GSI, 1977). The coalfield, which is roughly sickle shaped, is about 19km long and 38km wide and extends over an
area of 450 sq. km between latitudes 23°37'N and 23°52'N and longitudes 86°06'E and 86°30'E in Dhanbad district of (GSI, 1977) Jharkhand (figure-1.2). The Jharia Coalfield basin is a part of the east-west aligned Damodar-Koel Group of Gondwana basin of India. It preserves about 3000m thick succession of lower Gondwana (Permian) rocks within it. Out of four important sedimentary formations of the Jharia Coalfield namely-the Talchir, the Barakar, the Barren Measures and the Raniganj, only the Barakar and the Raniganj formations are important from coal extraction point of view. Administratively the Jharia Coalfield is primarily urban one with its well-developed transportation, rail and road, linkages. There are more than 200 urban settlements in and around the coalfield. It has a total population of about 4.75 Lakh residing into 63 administrative panchayats. Port of Kolkata and Paradip on one hand and industrial town of Jamshedpur and Bokaro on the other hand are at close distance from the coalfield. The Howrah-Delhi Grand Chord Railway line of Eastern Railway passes adjacent to the coalfield in the north from its nearest important railway station. Grand Trunk Road (NH2) connecting Delhi and Kolkata passes north of the coalfield whereas NH34 connecting Dhanbad with Ranchi passes through the coalfield.

1.4.2 Coal Reserves and its Chemical Properties

By the end of 19th Century the importance of the Jharia Coalfield as an important source of good quality coal has been already established. However, the estimation of its total reserves varied with various explorations. In 1880s based on various studies geologist estimated the total coal reserve to the tune of 804M tons. Later, with new explorations this estimate rose up to about 20,000M tons, about 72 per cent of which are proved reserve up to the depth of 1200m (table-1.1). Though Jharia coals are regarded qualitatively good but they are not entirely free from unwanted chemicals (table-1.2). It is clearly evident that the coal of the Barakar Formation is in general of higher quality than the Raniganj Formation. The Barakar Formation has higher carbon content and higher calorific value. It also has lower moisture and ash content than the Raniganj Formation. But as far as presence of sulfur and phosphorous are concerned the latter formation is a bit of better quality. Within the Barakar Formation, CIL (1993) admits
that the coal seams XIII and above are generally thin and of relatively superior quality. Seams XII to IX/X are of medium to superior quality and attain sizeable thickness at places. The V, VI, VII, IV, III and II are generally thick seams of inferior quality. The bottom most seam I is of superior or medium coking quality in the eastern part of the Jharia Coalfield. The Raniganj seams are thin and of medium coking, high volatile quality (Further details of different measures are discussed in geological section).

1.4.3 History of Mining and Land-use

Historically the Jharia Coalfield is one of the oldest coalfields of the nation. Its exact date of discovery is still debatable but according to Singh (2003) it was known to the people since 20th June 1771. No serious effort has been made until 1894 to mine coal from the coalfield. In fact the history of coal mining in the region is associated with the development of railway in the region. By 1898, the East India Company and some other private operators started functioning in the region and since then the mining keeps intensifying year after year, with some fluctuations, in response to the increasing demand (table-1.3). The production and profitability of different companies increased continuously and reached its first peak by the time of the First World War. The coal production was only 10 Lakh ton in 1896 which rose up to 110 Lakh ton by the year 1918. In this first phase of coal production large numbers of leases were allotted without considering their size and ecological viability. Any environmental considerations never become part of coal production during this phase. The first mine fire in a coal mine in the coalfield started in 1916 at Bhowrah Colliery (AEPG, 1988).

After the First World War, the coal demand and thereby coal production both trapped under the ill effect of worldwide depression. With decrease in coal demand some attention were given to check the haphazardly growing mining in the area, but it remained only a lip services to the environmental problem of the area.
Figure: 1.2 Location map of the Jharia Coalfield
### Table: 1.1 Coal reserves of the Jharia Coalfield

<table>
<thead>
<tr>
<th>Category</th>
<th>Depth (in meters)</th>
<th>Proved Reserve</th>
<th>Inferred Reserve</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific Coking Coal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-600</td>
<td>3715.8</td>
<td>323.2</td>
<td>4039</td>
<td></td>
</tr>
<tr>
<td>600-1200</td>
<td>512.0</td>
<td>749.0</td>
<td>1261</td>
<td></td>
</tr>
<tr>
<td>0-1200</td>
<td>4227.8</td>
<td>1072.2</td>
<td>5300</td>
<td></td>
</tr>
<tr>
<td><strong>Medium Coking Coal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-600</td>
<td>3843.7</td>
<td>223.3</td>
<td>4067</td>
<td></td>
</tr>
<tr>
<td>600-1200</td>
<td>242.0</td>
<td>1855.0</td>
<td>2097</td>
<td></td>
</tr>
<tr>
<td>0-1200</td>
<td>4085.7</td>
<td>2078.3</td>
<td>6164</td>
<td></td>
</tr>
<tr>
<td><strong>Non-Coking Coal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-600</td>
<td>5169.4</td>
<td>932.6</td>
<td>6102</td>
<td></td>
</tr>
<tr>
<td>600-1200</td>
<td>496.0</td>
<td>1355.0</td>
<td>1851</td>
<td></td>
</tr>
<tr>
<td>0-1200</td>
<td>5665.4</td>
<td>2287.6</td>
<td>7953</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0-1200</td>
<td>13978.9</td>
<td>5432.1</td>
<td>19417</td>
</tr>
</tbody>
</table>

*Source: After Singh, 2003.*

### Table: 1.2 Chemical properties of the Jharia Coals

<table>
<thead>
<tr>
<th>Geological Formations</th>
<th>Seams</th>
<th>Moisture</th>
<th>Ash</th>
<th>Sulfur</th>
<th>Phosphorous</th>
<th>Volatile Matter</th>
<th>Calorific Value (Kcal/kg)</th>
<th>Carbon</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raniganj Formation</strong></td>
<td>Mohuda, Lohapati, etc.</td>
<td>1.5-2.2</td>
<td>20-25</td>
<td>0.5-0.7</td>
<td>0.20-0.40</td>
<td>36-40</td>
<td>8440-8550</td>
<td>85-87</td>
<td>5.4-5.8</td>
</tr>
<tr>
<td><strong>Barakar Formation</strong></td>
<td>I-VIII</td>
<td>0.6-1.5</td>
<td>18-35</td>
<td>0.5-0.8</td>
<td>0.05-0.30</td>
<td>17-28</td>
<td>8550-8890</td>
<td>90-93</td>
<td>4.5-4.9</td>
</tr>
<tr>
<td></td>
<td>IX-XVIII</td>
<td>0.6-2.0</td>
<td>15-25</td>
<td>0.5-0.7</td>
<td>0.05-0.30</td>
<td>22-35</td>
<td>8440-8890</td>
<td>87-91</td>
<td>4.6-5.4</td>
</tr>
</tbody>
</table>

*Source: After CIL, 1993.*
This lull in coal mining activities in the Jharia Coalfield continued up to the Second World War when again coal demand peaked up. Fearing price rise, the Government first time resorted to control the selling of coal and selling of good quality coal to the Government at fixed price made compulsory. By the same time plans had been formulated to motivate the mine owners to boost the coal production. By and large early mining in this coalfield remain in the hands of private entrepreneurs who for their limited profit means mostly invested in cheap outcrop mining areas and a number of small mines within small leasehold areas opened by numerous entrepreneurs formed the scenario of the coalfield with unsatisfactory operations (AEPG, 1988).

<table>
<thead>
<tr>
<th>Year</th>
<th>Production (values in Lakh ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1894</td>
<td>0.015</td>
</tr>
<tr>
<td>1896</td>
<td>10</td>
</tr>
<tr>
<td>1901</td>
<td>20</td>
</tr>
<tr>
<td>1906</td>
<td>60</td>
</tr>
<tr>
<td>1918</td>
<td>110</td>
</tr>
<tr>
<td>1920</td>
<td>120</td>
</tr>
<tr>
<td>1950</td>
<td>126</td>
</tr>
<tr>
<td>1971</td>
<td>160</td>
</tr>
<tr>
<td>1983</td>
<td>247.4</td>
</tr>
<tr>
<td>1986</td>
<td>217.6</td>
</tr>
<tr>
<td>1987</td>
<td>243.4</td>
</tr>
<tr>
<td>1993</td>
<td>231.2</td>
</tr>
</tbody>
</table>


This blindfold effort to increase coal production resulted into large scale unscientific mining and gave birth to large scale coal fire, land subsidence and other environmental problems in the area. Two report, ‘The Coal Mining of 1936’ and ‘Indian Coalfield Committee of 1945’ have glimpses of these problems.

Since independence, the demand for coal as an important source of energy for our planned industrialisation and other uses increased continuously. Based on the ‘Working Committee’ recommendations in 1951, National Coal Development
Corporation was formed with the aim of scientific mining and nationalisation of coal mining. In 1955, ‘Mehta Committee’ recommended integration of all those mining leases which have output less than 2500 tons per month or which are less than 100 acre in size. But no heed has been paid to it. Under controlled price regime the profit margin of companies decreased and therefore up to 1970 no significant new investment in this sector came from private ownerships. As a result the working of mines remained least environmentally concerned however the coal production of the coalfield increased from 126.9 Lakh ton in 1950 to 160.0 Lakh ton in 1971 when nationalization of coal mining begin. The haphazard and unscientific mining of the valuable prime coking coal by the erstwhile owners without any regard to conservation compelled the government to nationalise the coal industry to meet the growing demand of coking coal in the country and it completed in two stages 1971 and 1973 (AEPG, 1988).

The Gulf Crisis of 1970s and consequent oil price rise, once again established the importance of coal as a reliable cheap source of energy. This was the decade when large scale open cast mining was planned and started in the Jharia Coalfield. In 1978, with the help of Polish experts the whole area was planned to be divided into 9 open cast and 23 underground blocks for scientific and economic mining. There after coal production, with some fluctuations, increased up to about 300 Lakh ton in 1994-95. After this period Singh (2003) observes a decline in production as a result of poor implementation of different coal production plan and to some extent due to cheap import of quality coal by steel industry after 1991 liberalisation. Thus with increased competition from abroad, decrease in profit margin, lack of management commitments and pressure to maintain the output level, environmental management plan never remain central to coal production in the area.

Thus being the chief storehouse of good quality coal in the country, this field has experienced extensive mining since 1925, when need of land protection was beyond realisation (Ghosh, 1991). As a consequence, mining activities of those days were conducted without any plan for land reclamation, leaving many unfilled pits, unreclaimed quarries and overburden dumps (Ghosh, 1987). This has caused widespread topographic disturbance as Mehta (1957) observes, “the area has undergone tremendous development and transformation in the last 25 years, so that the old topographic details
are no longer there at many places". Such unplanned mining caused massive damage to the environment particularly to the land of the area before nationalisation when some environment aspects were incorporated in coal mining. However, damage due to pre-nationalisation mining operations like fire and subsidence in old pits, abandoned quarries, old overburden dumps are resulting emergence of wastelands (old and new) even in the present days, producing land degradation in retrospective effects (Ghosh, 1991).

Thus the continuously increasing mining activities in the Jharia Coalfield have completely altered the land-use pattern of the area by excavation, overburden dumping and other activities related to mining (Ghosh, 1999). More and more land have been coming in the fold of mining operations, decreasing the forest and agricultural areas. The increase in mining activities also resulted in considerable increase in population and consequent increase in the area of settlement (AEPG, 1988). Clearly, due to coal mining and allied activities the land use pattern in the Jharia Coalfield has undergone radical changes over the last century (table-I.4, figure-1.3).

The mining in the last hundred years and so has changed drastically the entire landscape and today it is probably regarded as one of the most polluted coalfield of the country. Some important features of the coalfield are outlined here-

(i) A considerable portion of the area, about 35 sq. km, has been subsided. It has become difficult to identify suitable area for caving in the underground mines and thereby reducing coal productivity with increasing cost. According to an estimate some portion of Jharia town is facing subsidence danger. The Dhanbad-Jharia road subsided in 2001 and such problems may further aggravate. These subsidences are not only causing damage to surface structure but also social problems.

(ii) About 18 sq. km (more than 70 mines) are facing mines fire. These fires are not only polluting air and creating other health hazards to humans but also causing loss to valuable flora and fauna of the area, danger to coal extraction in such areas, direct loss to important fossil fuels and consequent land subsidence.

(iii) Coal refuses/overburden dumps accounting about 6.5 sq. km of coalfield area where as abandoned open cast pits accounting about 4.5 sq. km of the area.
(iv) There are more than 120 urban and rural settlements covering about 30 per cent (in 1993) of the coalfield area and most of them are unplanned settlements. This has not only aggravated danger potential of land subsidence in some areas but has also blocked extraction of some valuable minerals found near the surface through opencast mining in other areas.

(v) Most of the core and buffer zone of the coalfield has denuded forest cover and facing danger of acute soil erosion.

(vi) Based on the soil properties of the area an estimate has found that about 80 per cent of the area can be used for good to moderate cultivation activities but these are facing land degradation problems/threats due to spread of mining wastes and soil erosion.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Land-use/Year</th>
<th>1925</th>
<th>1974</th>
<th>1987</th>
<th>1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Settlements</td>
<td>8.6</td>
<td>16</td>
<td>32.3</td>
<td>33.1</td>
</tr>
<tr>
<td>2</td>
<td>Mining use including Open Pits</td>
<td>4.7</td>
<td>17.4</td>
<td>12.5</td>
<td>19.42</td>
</tr>
<tr>
<td>3</td>
<td>Water Bodies</td>
<td>7.3</td>
<td>6.7</td>
<td>3.1</td>
<td>2.9</td>
</tr>
<tr>
<td>4</td>
<td>Forests(Plantations)</td>
<td>4.9</td>
<td>0.7</td>
<td>0.7</td>
<td>2.45</td>
</tr>
<tr>
<td>5</td>
<td>Agriculture &amp; Natural Vegetation</td>
<td>65.4</td>
<td>56.8</td>
<td>49.4</td>
<td>39.02</td>
</tr>
<tr>
<td>6</td>
<td>Fallow &amp; Pasture</td>
<td>9.1</td>
<td>2.4</td>
<td>2</td>
<td>3.11</td>
</tr>
</tbody>
</table>

Table: 1.4 Land-use pattern in the Jharia Coalfield (values in per cent)


A rough estimate of the Jharia Coalfield has shown that about three fourth of the coal reserves are still workable and so the coalfield needs a long term perspective planning. It has been also anticipated that if the mining and allied activities will go in same fashion the entire coalfield, in 30 years or so will have a deserted and bleak outlook. Therefore analysis of land degradation in the coalfield is of much use not only for its capability of identification of degraded lands but also for its support to suitable environmental management plan of the area.
Figure: 1.3 Land-use of the Jharia Coalfield in 1925, 1974, 1987 and 1993.
1.5 Objectives of the Study

Following are the main objectives of the present study:

(A) To identify, map and determine the extent of land degradation in the study area.
(B) To study the nature and degree of degraded land in the area.
(C) To assess the impact of coal mining on land.

1.6 Research Questions of the Study

Following are the research question to achieve the above mentioned objectives concerning the present study:

(A) What are the different types of degraded land in the coalfield?
(B) How much area is under the degradation?
(C) What is the status of soil quality in the study area?

1.7 Data Base

Following are the important primary as well as secondary data sources for the present study-

Secondary Sources:
(A) Various literatures related to the proposed study
(B) Topographical Sheet (Scale 1: 50,000 by SOI; Sheet No.731/1,2,5,6)
(C) Geological map of the Jharia Coalfield (1 inch:1 mile; by GSI; 1964)
(D) Satellite Images.

Primary Sources:
(a) Field observations (b) Soil Sample Collection and Analysis (c) GPS Readings.
1.8 Methodology

Any land degradation study in coal mining areas requires a very comprehensive approach. Keeping in mind the nature of the problem for the present study following set of methodologies have been used to achieve different objectives:

(i) Basic information regarding history, general outline of the area, administrative setup, physiographical characteristics etc. have been gathered from topographic sheet (1:50,000; SOI); GSI Map (1inch:1mile) and available extensive literatures on the area.

(ii) In next step conventional and non-conventional methods have been used to identify different type of degraded land in the area.

(iii) Further satellite images have been used to identify the extent of degraded land. It was followed by direct field observations to avoid any misrepresentation.

(iv) To study degree of land degradation in the area soil samples were collected and analysed chemically in laboratory.

(v) Thus generated all land characteristic data were analysed with reference to location and type (underground and opencast) of different mines in the area.

1.9 Organisation of Materials

Keeping in mind the comprehensive nature of the problem, the present study has five chapters dealing with different aspects.

The first chapter is 'Introduction to the Study Area'. It gives general information about the idea of land degradation, study area, objectives, hypothesis, data sources, methodology etc.

The second chapter is the study of 'Physiographical Characteristics of the Jharia Coalfield'. This chapter gives a detail description of physiographical characteristics of the study area like geology, geomorphology, climate, etc. and the implication of different physiographical characteristics for land degradation in the study area.
The third chapter 'Land-use Study of the Jharia Coalfield' covers detail discussion on different land-use of the coalfield with special reference to land degradation in the study area. It gives an account of different types of degraded land and also covers in depth analysis of their extent and degree of degradation.

The next chapter is 'Soil Characteristics of the Jharia Coalfield' which gives a detail account of soil quality status in the study area. It is based on physical and chemical analysis of different soil samples and their interpretation.

Finally in the last chapter titled 'Conclusions', an integrated discussion with conclusions based on all the previous observations have been presented.