# APPRAISAL OF VEGETATION STATUS IN MINED AREAS OF SIRMAUR DISTRICT IN HIMACHAL PRADESH

*THESIS*

*by*

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# Certificate-I

This is to certify that the thesis entitled, **"Appraisal of vegetation status in mined areas of Sirmaur district in Himachal Pradesh."** submitted in partial fulfillment of the requirements for the award of degree of **Master of Science in Forestry (Silviculture)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) is a bonafide research carried out by **Mr. Syed Mubashir Hanief (F-2002-03-M)** under my guidance and supervision. No part of this has been submitted for any other degree and diploma.

The assistance and help received during the course of investigations has been fully acknowledged.

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Dated:

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# Certificate-II

This is to certify that the thesis entitled, **"Appraisal of vegetation status in mined areas of Sirmaur district in Himachal Pradesh"** submitted by **Mr. Syed Mubashir Hanief (F-2002-03-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) *in partial fulfillment of the requirements for the award of degree of* **Master of Science in Forestry (Silviculture)** has been approved by the student's advisory committee after an oral examination of the same *in* collaboration with the external examiner.

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بسم الله الرحمن الرحيم

(In the name of Allah, the most Beneficent and the most Merciful)

---

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(Syed Mubashir Hanief)

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# INTRODUCTION

# CHAPTER-I

# INTRODUCTION

Mineral ore is one of the natural resources available in a particular site and the process of mining involves extraction of the desired ore (mineral) present under the crust of earth. Mining industry is next only to agriculture and is spread over vast areas all around the world (Paulsamy *et al.*, 1996). Though mining of minerals has an important role in the economic development of the country but its adverse role in deteriorating the environment cannot be overlooked. Surface mining produce scars and results in the inversion of natural soil substratum sequence. Not only the existing vegetation is destroyed due to dumping of huge amounts of overburden on the adjacent mine free land but there is also loss of soil. Huge acreage of land lying abandoned after mining has led to environmental and land degradation problems. The first impact of any mining activity is removal of vegetation and subsequently increases soil erosion (Soni *et al.*, 1989).

In an estimate, it is contended that in the last quarter of previous century total degraded land on account of mining was nearly 24 million ha or 0.2 per cent of earth total surface (Soni *et al.*, 1986). In India the scenario is no better, there are approximately 5500 mines covering an area of eight million hectares (Tiwari, 1994). Most of these mines give emphasis for economic output only without paying much heed to environment degradation. Thus it is evident that significant degraded lands are added every year. In Himachal Pradesh the area under mining has been estimated to an extent of 3200 ha (Sharma, 1997). Mismanagement and the improper exploitation of these non-renewable resources has not received due attention in developing countries like India due to the sporadic distribution of the mines primarily in the remote areas, affecting only poor population and administration of this industry by the economically powerful section of society.

Himachal Pradesh is a mountainous state and covers an important segment of Western Himalayas extending from plains of Punjab and Haryana up to Tibetian border with an area of 5,5673 sq km, constituting 1.69 percent of total geographical land area of India and 10.54 percent of Himalaya. This state has prime role in maintaining its perennial rivers feeding the nearby low lying states like Punjab, Haryana etc. Thus, the ecological sustainability of this area is most wanting.

Sirmaur district is the southern most part of Himachal Pradesh,.spreading over 2,825 sq. km. It is famous for its limestone mining, with 5.07% of the total area of Himachal Pradesh and is divided into six tehsils viz. Nahan, Poanta-Sahib, Renuka, Rajgarh, Shillai and Pachhad. The total area under mines in this district is approximately 10.94 sq. km. constituting 0.39 per cent of the total geographic area of the district (Agnihotri *et al*, 1998).

In mined areas, ecosystems are drastically changed and original land uses, socio-economic and cultural patterns are disturbed. But some experts believe that mining in district Sirmaur is not a threat to the ecology and environment of the area. Instead the mining had sustained economic growth backed by strong community consciousness and environmental awareness among the locals.

During mining activities overburden strata displacement may contain certain materials that may be unfavourable or potentially unfavourable to plant growth. Several workers have identified salinity, acidity, poor water holding capacity, inadequate supplies of plant nutrients, high rates of litter accumulation, accelerated rates of erosion and degraded spoil texture, as major problems in mine spoils that affect revegetation processes. (Down, 1975; Archibold, 1980; Jha and Singh, 1990). As regards to plant nutrients, several investigators have reported N and P as limiting growth factors in mine spoils. Day et al. (1979) observed that even with adequate irrigation but without proper fertilization, plant growth in spoils and top soil materials was extremely poor.

Sometimes disturbances are so severe on the mined sites that all the vegetation and even the plant propagules are completely eliminated. Once the vegetation of a site gets disturbed, it takes decades to reach its original form. Though natural succession proceeds towards the original vegetation, but the process is very slow and disturbance at any stage of succession may push back it to several stages formed earlier. It has been reported (Soni *et al*, 1989) that reclamation is a speedy way to revegetate a site and helps in achieving richer species diversity as compared tom natural forests. The primary purpose of reclaiming these disturbed lands is to stabilize the mine spoils and prevent them from being eroded by winds and flash floods. Another important purpose of reclaiming the mined area is to rehabilitate them so that the general productivity will be greater or equal than the former productivity level.

Taking into account the above complexities in mined areas and their impact on the socio-economic status of the inhabitants, the study have been put forward to ascertain the number of mines, production output, socio-economic effects and vegetation succession in abandoned mines with the following objectives:-

1. Survey, distribution, bio-physical status and classification of mined areas.
2. Revegetation processes in abandoned mines.
3. Socio-economic status of inhabitants of selected mined areas.

# REVIEW OF LITERATURE

# CHAPTER-II

# REVIEW OF LITERATURE

Mining is responsible for adversely affecting the natural resource components of the mined ecosystem be it be vegetation, soil, water, fauna or the microclimate. Restoration of the natural resources in a mined land depends on the ecological amelioration of the depleted ecosystems. A fundamental understanding of ecosystem structure and functioning including the processes of primary and secondary succession are to be well conceived to achieve a quick and reliable restoration. In order to provide sound explanation for the results obtained under this study by reviewing the information available on the following aspects of study:

**2.1** Mining and society

**2.2** Vegetational survey and successional studies

**2.3** Mining and change in physico-chemical characteristics of soil

## 2.1 Mining and society

Random sampling often accompanied by stratified random sampling is advocated for conducting socio-economic surveys for investigating various social and economic factors dependent on any major man's activity. Gupta (1981) has given the advantages of random sampling; there is no possibility of personal bias affecting the results, the analyst can easily assess the accuracy of the estimate because sampling errors follow the principles of chance, it enables the analyst to provide the most reliable information at the least cost. Socio-economic survey of any area is done through prescribed questionnaires. The questionnaire commonly encompass parameters like area, educational status, number of males and females in a family, landholding of family, educational status, livestock , per capita income, cropping pattern, farming systems etc. Kothari (1990) advocated questionnaire is free from bias of the interviewer; respondents have adequate time to give well thought out answers and large samples can be made use of and thus the results can be made more dependable and reliable. Often finite number of units are selected for conducting surveys. These units are dependent on the area and density of the population. Further often these parameters are minimized, keeping in view the time and man-days. Rathore *et al* (1975) selected 25 farmers, for each crop, for conducting survey on five commercial crops in Himachal Pradesh. Likewise, Chand and Tewari (1992) opted for 30 households for taking observations on women's role in irrigated hill agricultural system.

In the socio-economic survey of Uttar Pradesh hills under limestone quarries Sikka *et al* (1984) reported that limestone quarrying is providing employment to the people in the area and 61 per cent of the income of the people is derived from working in quarries.

Bhattacharya *et al* (1986) concluded that in Rajasthan women working in mines are not only deprived of their right of freedom but also of minimum wages.

Agnihotri *et al* (1998) reviewed mining scenario in district Sirmour and its socio-economic impact and concluded that mining has played a significant role in economic upliftment of the people in the area; positive socio-economic impacts of limestone mining in the area far out-weigh the adverse impacts. They emphasized that there is still ample scope and need for co-existence of mining and environment.

Panwar (1999) conducted socio-economic survey of mined areas of district Solan (H.P.) and reported that limestone mines provide employment to local people. The survey also revealed some negative effects of mining like drying up of water resources, noise pollution, dust pollution, social insecurity among women etc.

## 2.2 Vegetational survey and successional studies

The functioning of a community is intimately related with its components. The components vary in quality as well as in quantity and impart a structure to the community. The structure of a community can be studied by taking into consideration number of characters. Raunkiaer (1934) advocated the use of quadrat and line transact method to obtain the frequency of a species. Density and frequency taken together is of prime importance in determining the community structures (Oosting, 1958). Importance value index (IVI) is used to express the dominance and ecological success of any species in a community (Phillips, 1959). To determine the structure of a community, vegetational survey is done either monthly, seasonally or during the peak growing period. Kumar *et al,* 1997 did vegetational survey during peak growing season by laying quadrats of 10m x 10m for trees, 5m x 5m for shrubs and 1m x 1m for grasses and herbs for density and frequency determination Floristic composition and tree size distribution of different forest patches in the sub-tropical montane forests of Parque Biologico Sierra de San Javier, Argentina was studied by laying quadrats (20 m x 20 m) sampled at 12 sites which were ordered using correspondence analysis (Arturi *et al,* 1998).

Revegetation process of an area involves sequential transformation of one type of community into another till climax. Succession is directional and orderly process, results from the modification of physical environment by the community and if given indefinite time, without disturbances, plant communities would approach to same composition and structure in a given climatic region (Clements, 1916). In any particular habitat in the landscape, if climax community may have been developed or may not yet have developed, the communities go through progressive development of parallel and interactive changes in environment and communities; a succession. Through the course of succession community production, height and mass, species diversity, relative stability and soil depth and differentiation tend to increase (Whittaker, 1953). There are several stages in the process of succession which a community has to pass through before it reaches the climax. Graham (1955) identified different stages in primary succession for xearch, mesarch and hydrach conditions. The actual composition of different stages depends upon species that has access to the site. The species which invade the bare land are called as pioneer species. These species have the capability to survive under adverse conditions. But as the time progresses these species are replaced by more diverse life forms. The early successional species alters the conditions or the availability of the resources in a habitat in a way that entry of the new species is possible, a process known as facilitation (Connell and Slayter, 1977). In succession there is no time period for each stage to begin and end. One stage may occupy the site for a long time at one sitê and less time at another. Succession does not necessarily begin with stage one and proceed through each successive stage in a unidirectional sequence (Spurr and Barnes, 1980).

Simple life forms inhabit the bare area and make the site environment conducive for the establishment of higher life forms. From the experiments undertaken in Kamrup and Goalpara divisions in Assam (De, 1941) concluded that *Eupatorium odoratum* acts as a nurse crop for Sal natural regeneration in its early stages of growth and found that grasses are not indicators of Sal soil nor is their introduction necessary to establish Sal regeneration. Likewise, Iven (1974) reported that *Eupatorium odoratum,* though a serious weed of agricultural plantations in Nigeria acts as a protective cover crop in early stages of tree establishment. *Eupatorium* spp. is a tropical, noxious, perennial weed of plantation crops and also of newly afforestated areas. Fruit production is prolific and achenes are disseminated by wind. It is a light demanding and has high regeneration capacity (Mogali and Hosmani, 1981; Papiya and Ramakrishnan, 2002). The drought-tolerant species, *Leptospermum scoparium was* recorded as the principal seral species on the denuded land slips in Florida (Mark, 1964).

Thomson (1943) reported plant succession is from weed flora for the first few years to a prairie flora and finally to a climax forest in the central Wisconsin sand plain area.

Nomoto (1956) made a study on successional processes of Beech to Oak forests in 3 stands near Tokyo and concluded that Oak forests would normally give way to Beech in process of time.

Bhatnagar (1960) evinced that succession in the dry and moist *Shorea robusta* forest types can be both progressive and regressive. The dry types ultimately degrade into a dry grassy savanna, after passing through mixed miscellaneous stages. The primary succession in dry Sal types starts from a grassland association leading to mixed miscellaneous stage. In moist Sal type, the primary succession starts from grasses and leads to mixed forests of Sal and *Terminalia tomentosa, Syzygium cuminii* etc after passing through mixed miscellaneous seral stages. The moist Sal type may however degrade to dry Sal type, then to mixed miscellaneous forest and ultimately to dry savanna.

Odum (1960) while estimating the organic production and turn over in old field succession in South California reported that dominants replace one another from year to year, the relative abundance in any one species is rarely same from one year to next and the number of individuals often increases, at least in the early years.

Seth and Bhatnagar (1960) reported that most reliable indicators for Sal regeneration are shrubs and grasses. The most reliable indicators of favourable conditions for Sal regeneration are *Clerodendron infortunatum* and *Moghania chappar*. *Saccharum spontaneum* is always a strong contra-indicator.

Puri and Jain (1961) studied succession of plant communities in Aravali ranges of Rajasthan and gave a scheme of classification, based on the observations of number of sites, in which tree species form the climax communities and grasses are present in the undergrowth, but nowhere dominant, and the apparent character of grassland is potentially a savanna or probably a tree community.

Gupta (1966) studied succession of the mixed Oak/ conifer forests in Garhwal Himalayas and reported that the succession of forest communities showed a definite trend, depending upon the surface geology, nature of the soil and biotic factors. The Oak forms the climatic climax; progress of communities to Oak climax is very slow.

Bullington (1968) studied secondary succession on abandoned pasture land in North Central Illinois which were previously oak forests and reported that trend of succession is towards xerophytic forest after 20 years; the trees of adjacent forest enter along the periphery and in central gullies.

Hulst (1970) concluded that relation between variable substrate and variable floristic composition is possible and the substrate conditions on individual mine site acts as an environmental sieve.

Buell and Buell (1971) studied succession from 1958 to 1969 in New Jersey and reported that mortality of previously established individuals was common during the early stages of succession. At first, when bare soil was exposed, frost heaving was an important hindrance to the early establishment of tree seedlings.

Wagner *et al* (1978) compared the plant species composition and diversity on adjacent mined and mine free area in New Mexico and found non-significant decrease in species diversity in mined sites of different ages and greater diversity in mine free areas. Mined sites of all ages were in a similar phase of early primary succession as shown by the dominance of annuals and short lived perennials.

Brenner (1984) experienced during restoration of surface coal mine lands in Northern U.S.A. that if the ultimate objective of reclamation is to create a diverse and stable ecosystem then initial reclamation should be designed to stabilize the site while providing a suitable habitat for natural succession.

Gibson *et al* (1985) concluded that natural process of ecological rehabilitation is governed by microclimate, soil properties, surrounding flora and disseminating efficiency of propagules.

Soni and Vasistha (1986) carried out reclamation of mine spoils for environmental amelioration in Doon valley and concluded that if local species are used for reclamation of mined area they are more suitable and better adapted as well as ecologically and economically viable.

Papp (1987) while studying secondary succession after deforestation in North Hungary reported that after 6 years the percentage of hemicryptophytes + geophytes + biennials, dropped from 91 per cent of herbs in the forest to 57-70 per cent in the cleared land.

Uhl *et al* (1988) presented data on vegetation composition, structure and above ground biomass accumulation of 13 forest sites in Eastern Amazonia that has been cut and burnt and reported that heavy use and the prevalence of burning in the abandoned pastures may prevent natural reforestation and lead to irreversible degradation of the sites.

Soni *et al* (1989) revealed that diversity of the plants on reclaimed surface mined areas of rock phosphate mines at Maldeota increased significantly after 4 years of reclamation and it was distinctly higher than the adjoining natural areas, lower and upper Himalayan moist temperate forests..

Jha and Singh (1991) concluded that time is an important factor in succession and increase in species diversity with the increase in age of mine soils is an ordered phenomenon.

Leak (1991) examined succession in northern broad leaved and spruce/hemlock forests of New Hampshire, U.S.A. by regressing percentage composition of the major species over stand age, using both temporary and remeasured plots, in stands ranging from 3 years to 190 years on three soil types. It was found that successional change varied by site and five ecological species roles were detected; dominating climax, stable climax, minor climax, persistent successional and temporary successional species.

Dwivedi (1992) gave special characteristics of colonizer species which are: abundant viable seed production, easy dispersal of seeds, easy germination of seeds, massive root system, low requirements of nutrients and water and are capable of growing in poorer sites.

Qaiser *et al* (1993) studied factors affecting natural regeneration of *Quercus leucotricophora* in Solan district of Himachal Pradesh and reported that the undergrowth of this forest type include common shrubs like *Berberis lycium* and *Myrsine africana.*

Soni *et al* (1994) planted various grasses, shrubs and trees on an abandoned limestone mine in Mussoorie hills and analyzed the vegetation after 3 years. It was found that many of the planted herbaceous species has disappeared and have been replaced by more aggressive species from adjoining mine free area. *Rumex hastatus* (not planted) has invaded the area and is the most frequent species.

Donfack *et al* (1995) studied the secondary succession in a semi arid tropical savanna region of North Cameroon in two series of formely cultivated fields, 1-35 years after abandonment. Floristic changes and the dynamics of woody plant populations were compared between areas with vertisols (clay texture) and sandy soils, as a function of length of abandonment. It was found that vegetation changed continuously during 35 years following field abandonment.

Nandeswar *et al* (1995) revealed that for an ecosystem approach of rehabilitation process it is necessary to understand the ecosystem structure, including the process of primary and secondary process.

Crowder and Harmsen (1998) studied changes in vegetation in plots of two abandoned hay fields at Lake Opinion, Canada and found that soil properties and spatial vegetation patterns were heterogeneous. Density of seedling and/or young clonal shoots was significantly related with the distance to a forest edge or to possible seed parents.

Ohtsuka (1998) studied old field succession in temperate regions and life history of the dominant species in U.S.A. and Japan and found that wind dispersed winter annuals or biennials easily invade the area and grow under the canopy of summer annual communities due to their shade tolerant rosettes. These were gradually succeeded by perennial grassland species.

Abdulfatih (1999) studied succession in the subtropical arid highland of Sana'a Republic of Yemen and observed that one and four years old abandoned fields were characterized by 6 and 32 species, respectively. Four years old abandoned field was characterized by more diverse and perennial life forms, with more humus and higher field capacity.

Ohtsuka (1999) studied community structure and floristic change in the early stages of tropical old-field succession, Sabat, North-East Bornea Island and found that dense therophytic communities established soon after abandonment and changed rapidly. These therophytic communities were replaced by perennial grasses and shrub species, within 3 years after abandonment.

Burslem (2004) demonstrated that disturbance to natural forests varies greatly in scale and effect in different forest types and for different disturbance agencies, such that robust generalizations are difficult to construct. A disturbance regime has components describing the intensity, frequency and extent of its effects. These properties are important because these may influence emergent properties of the forest community, such as species composition and tree diversity.

Verma *et al* (2004) evaluated species diversity in plantation raised on mine overburden areas near Poanta Sahib in Sirmaur district of Himachal Pradesh and found that distribution of most of the ground flora was contiguous. Index of dominance was lower while the index of diversity was higher for ground flora under the plantations compared to those in the exposed mine overburden area.

## 2.3 Mining and change in physico-chemical characteristics of soil

Allard (1942) suggested that during the process of succession, the absence of normal vegetation in patches surrounded by areas of the normal plant growth forming the climax woodland is due to the fact that soils are lacking in available phosphorus and nitrogen. The lack of sufficient available phosphorus prevents invasion of nitrogen fixing legumes.

Sumakov (1958) tabulated data on the chemical and physical changes in the soil after natural succession by birch on clear fellings in taiga spruce forests and concluded that this succession arrested the process of podzolization and increased fertility but is silviculturally undesirable.

Peterson and Nielson (1973) found great differences in properties among various mine and mill wastes. Tailings from Cu, Pd, Zn and U mills have one or more adverse characteristics such as poor physical properties, toxic substances, nutrient deficiencies, high acidity and alkalinity and salinity.

Schafer *et al* (1980) reported that soil structure developed more quickly near the soil surface (in 10-30 years) than below 10 cm (in 50-200 years) and this was attained more sooner in clayey than is sandy mine spoils. They further assumed that within a few decades many properties of the mine soils may approximate to those of normal soils.

Paulswamy *et al* (1996) studied an series of lime mine spoils of Madukkarai, Coimbatore and reported that mining depletes macronutrients viz. N, P, K, organic carbon and moisture capacity of the area. The nutrient content increased with the age of minespoils. Further, the age of mine spoils had an important bearing on the growth retardation of seedlings.

Soni *et al* (1989) studied physical and chemical characteristics of the mine area at Maldeota, Dehradun and concluded that pH and phosphorus of mined area has increased, whereas, organic carbon, sodium and potassium had decreased due to mining. They further reported that mining increases the sand and silt per cent, whereas, the clay content gets decreased.

Dadhwal and Singh (1993) compared the physical and chemical characteristics of mine spoil and normal soil. They reported that pH and bulk density was higher in mine spoils whereas, organic carbon, $CaCO_3$ and macro nutrients (N, P, K) decreased in mine spoils. They further reported that clay content has decreased from 26 percent to 12.5 percent in mine spoils.

Juyal *et al* (1995) employed USDA method for spoil classification at Shastradhara limestone mine watershed. The USDA method of spoil classification proved to be more useful in selecting appropriate plant species for revegetation of mine spoils.

Banerjee *et al* (1997) studied the effect of age on vegetation on coal mine spoils influenced by microsites at Surgaga district (M.P.) and found decrease of coarse fragments and increase in finer fraction of mine spoil with age. They also reported increase in nutrient content and organic carbon with the increase in age of mine spoil.

Berendse *et al* (1998) investigated vegetation and soil development during succession in coastal dune slacks on Terschelling Island, Netherland and found that nitrogen mineralization was extremely low increasing from 0.2 gm $year^{-1}$ after 5 years to 0.8 gm $year^{-1}$ after 76 years, accompanied by decline of pH in the upper 10 cm of soil from 6.8 to 4.4.

Masoodi (1999) studied changes in physical properties at various stages of soil development on restored soils developed from the spoil material of the open cast limestone at Dehradun and found that in the rooting zone (0-25 cm) physical properties were generally less favourable in mined soils than reference soils. Mine soils had higher bulk density and coarse fragments; lower porosity, clay content and water holding capacity than reference soils at a comparable depth.

Panwar (1999) studied the physico-chemical characteristics of soil in mined and mine free area of district Solan, Himachal Pradesh and concluded that mining increases the sand content, coarse fragments, slope of area and consequently decreases the nutrient and clay content. He also classified mined areas as per the USDA method of mine spoil classification.

# METHODOLOGY

# Chapter-III

# MATERIALS AND METHODS

The present investigation was undertaken to locate and classify different types of mines, study effect of mining on flora and revegetation processes in abandoned mines in Sirmaur district of Himachal Pradesh. The details of the area, material used and techniques followed during the course of the study are given in this chapter.

## 3.1 DESCRIPTION OF THE AREA

### 3.1.1 Location

The district Sirmaur forms the south-eastern part of Himachal Pradesh. The district is bounded by Shimla district in the north, the river Tons and Yamuna in the east, district Ambala of Haryana in the south and district Solan in west and north-west. It lies in the outer Himalayan ranges, called as Shiwaliks, between 77°1′12″ and 77°49′40″ east longitudes and 30°22′30″ and 31°1′20″ north latitudes. Total area of the district is 2825 sq. km. Longest length from west to east is 77 kms and the maximum width from north to south is 80 kms. The elevation of the lowest point on the southern boundary of the district is 1400 feet above mean sea level and the highest point in the north is 12000 ft (Churdhar) above mean sea level.

### 3.1.2 Climate

#### a) Temperature

The temperature in the different parts of the district Sirmaur varies according to the elevation. The temperature of the district ranges between $3.5^0$C to $36.8^0$C. The temperature starts increasing gradually from February till June, which is the hottest month of the year. With the onset of monsoon by the end of June there is decrease in temperature. After the withdrawal of monsoon by the mid September, temperature decreases gradually at first and fairly rapidly after November. Coldest month of the year is generally January.

### b) Precipitation

The annual precipitation received by the district is in the range of 1394.40 mm to 1677.10 mm. Nearly 85% of the annual rainfall is received during the period June to October. July and August receive the maximum rainfall. At higher elevations, north-eastern portions of the district receive precipitation in the form of snow in the winter season.

### c) Soil type

The soils of the district Sirmaur belong to the brown hills and alluvial genetic group (Verma,*et al.* 1985 ). These soils are generally of coarse texture comprising of loamy sand and sandy loam and occasionally loam to sandy clay loam. The soils are mostly neutral in reaction alkaline and have medium to high contents of organic matter.

### d) Vegetation

The high forest consists of *Quercus* spp., *Abies pindrow*, *Picea smithiana* and *Pinus wallichiana*. Apart from them, there are *Cedrus deodara* forests in the north of the Giri river mixed with *Pinus roxburghii*. In the Dharthi ranges and Cis-Giri area, *Pinus roxburghii* forests are of great value for the extraction of the resin. *Shorea robusta* forests occur in the east of Nahan. Pure *Shorea robusta* is gradually replaced by dry tree species like *Terminalia tomentosa*, *Boswellia serrata*, *Anogeissus latifolia* and scrubs on hot, dry and poor localities. *Eulaliopsis binnata* grows in the lower elevations, which is of great value and bamboos as mixed plantations.

## 3.2 IDENTIFICATION OF MINES

Preliminary information about the distribution of the mines in the district Sirmaur was gathered from the Mining Department of Himachal Pradesh. Based on this information, the whole district was divided into three sections viz. Sataun, Rajpura and Sangrah on the basis of concentration of mines in these areas. In Nohradhar since mining is at initial stage hence it was combined with Sangrah section for conducting survey. During the survey information regarding the following parameters was collected viz. area allotted for mining, active mining area, lease period, condition of mine (working, abandoned or closed), vegetation, socio-economic data, soil samples and mines that are not in records of Mining Department of Himachal Pradesh.

## 3.3 SOCIO-ECONOMIC STUDIES

Socio-economic survey of each section viz. Sataun, Sangrah and Rajpura was simultaneously done at the time of identification of mines in the month of March - April. Thirty people were selected randomly from the villages around mines in each of the section and interviewed for their opinion on effect of mining on the economy of the local inhabitants, problems faced by them (dust pollution, noise pollution, water scarcity, fodder, fuel wood etc.) change in cropping pattern, impact on flora and fauna and agricultural productivity.

The proforma for socio-economic survey has been appended in Annexure I.

## 3.4 SELECTION OF SITE FOR VEGETATION ANALYSIS

Limestone mines are the prominent type of mines in the district Sirmaur. Thus, limestone mines were considered for detailed vegetation analysis. Based on the accessibility, type of vegetation and location; following forest areas/ mines were selected for further investigation regards degradation of vegetation and regeneration process in them through natural succession or reclamation by artificial plantation.

(a) Sal forest zone

(i) Pure Sal forest: - This forest occurred adjacent to the active mining site of Cement Corporation of India (Rajban).

(ii) 6 year's old abandoned mined site: - An area of around 5 bighas was left abandoned after mining in Cement Corporation of India mine.

(iii) 13 year's old artificially reclaimed site: - An area of 10 bighas was reclaimed after mining by Cement Corporation of India.

Cement Corporation of India (Rajban) is situated 60 kms from Nahan covering an area of 255.30 bighas, located at an altitude of 780-840 meters above the mean sea level.

(b) Dry mixed deciduous forest zone

(i) Phoenix dominated site: - This site occurred adjacent to the abandoned mines on western aspect.

(ii) Phoenix – Acacia dominated site: - This site also occurred adjacent to the abandoned mines on northern aspect.

(iii) 5 year's old abandoned mine

(iv) 10 year's old abandoned mine

(v) 18 year's old abandoned

These abandoned mines of different ages were situated in dry mixed deciduous forest 3-4 kms from Phoenix dominated site and Phoenix –Acacia dominated site covering an area of around 4 bighas, 6 bighas and 7.5 bighas, respectively, at an altitude of 1200-1250 meters above mean sea level.

(c) Quercus forest zone

(i) Pure Quercus forest: - This forest occurred adjacent to the active mining site of Jai Singh Thakur (Bohar).

(ii) 8 year's old abandoned mined site: - An area of 5 bighas was left abandoned after mining in Jai Singh Thakur's mine.

(iii) 12 year's old artificially reclaimed site: - An area of 7 bighas was reclaimed after mining in Jai Singh Thakur's mine.

Jai Singh Thakur's mine (Bohar) is situated 88 kms from Nahan covering an area 49.6 bighas of located at an altitude of 1700 – 1725 meters above the mean sea level.

### 3.4.1 Vegetational studies

Vegetational analysis in each forest area / abandoned mine / reclaimed area was done by laying out sample plots of 0.1 ha in each area and following observations were taken:-

(a) Trees:-

Tree characteristics in each sample plot were studied from plot of size 10 x 10 $m^2$ replicated thrice.

(i) Diameter

Sapling diameter was measured at 2.5 cm above ground level and trees it was measured at 1.37 meter above the ground level.

(ii) Number of species of trees.

(iii) Number of individuals of each species.

(b) Shrubs:-

Following shrub characteristics were studied by laying 5 quadrats of 5m x 5m in size in each sample plot of 0.1 ha.

(i) Diameter

20 stems of each species were selected and their diameter was measured by Vernier Calliper. The average diameter of these selected stems was calculated.

(ii) Number of species of shrubs.

(iii) Number of individuals of each species.

(c) Grasses/ Herbs:-

The characteristics of the herbaceous vegetation were studied by laying 10 quadrats of 1 m x 1 m in size in each sample plot of 0.1 ha.

(i) Girth

For herbaceous vegetation circumference was determined following Hanson and Churchill, 1961.

(ii) Number of species of herbs.

(iii) Number of individuals of each species.

From the above observations the following parameters for the vegetation were calculated:-

(i) Basal area was calculated using formulae $\Pi d^2/4$ for trees and shrubs and $g^2/4\Pi$ for herbaceous vegetation.

(ii) $$\text{Frequency} = \frac{\text{No. of quadrats in which the species occurred}}{\text{Total no. of quadrats studied}} \times 100$$

(iii) $$\text{Density} = \frac{\text{Total no. of individuals of a species}}{\text{Total no. of quadrats studied}} \times 100$$

Following Phillips (1959), important value index (IVI) was calculated for trees, shrubs and herbaceous vegetation in each sample plot

$$\text{Relative dominance} = \frac{\text{Total basal area of a species}}{\text{Total basal area of all species}} \times 100$$

$$\text{Relative density} = \frac{\text{No. of individuals of a species}}{\text{No. of individuals of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{No. of occurrence of a species}}{\text{No. of occurrence of all species}} \times 100$$

IVI = Relative Dominance + Relative Density + Relative Frequency

The value of IVI denotes the dominance and ecological success of a species.

### 3.5 COLLECTION OF SOIL SAMPLES

The soil samples were taken from each mined site in order to classify them and to assess the physio-chemical characteristics of the soil. Each mine was divided into different (4-10) sections depending upon the size of the mine and composite soil samples were taken from 0-40 cm. However, in sites selected for vegetation analysis similar procedure was followed but separate composite soil samples were taken form 0-20 cm and 20-40 cm. In abandoned mines of the dry mixed deciduous forest soil samples could be taken from 0-20 cm alone as there was hard pan in lower horizon of soil.

## 3.5.1 OBSERVATIONS

### a) Soil

To assess the physio-chemical characteristics of soil of sites selected for vegetation analysis, samples taken were air dried and passed through 2mm sieve. The processed soil samples were subjected to physico-chemical analysis using the method/procedures given below:-

**Methods employed in physico-chemical analysis of soil**

| Name of Element | Method Employed |
|---|---|
| **Physical Analysis** | |
| Soil Separates | International Pipette method (Piper, 1966) |
| Bulk Density | Weighing Bottle method (Singh, 1980) |
| **Chemical Analysis** | |
| pH | 1:2.5 Soil Water Suspension (Jackson, 1973) |
| Organic Carbon | Walkley and Black's rapid titration method outlined by Piper (1966) |
| Available Nitrogen | Alkaline Potassium Permagnate method (Subbiah and Asija, 1956) |
| Available Phosphorus | Sodium Bicarbonate method (Olesen *et al.*, 1954) |
| Available Potassium | Neutral Normal Ammonium Acetate method (Merwin and Peech, 1951). |

### b) Classification of the mined areas

The soil samples collected from all mines were analyzed to categorize the mines into different classes as given by United States Department of Agriculture (USDA).

The soil samples were passed through the 2mm sieve to determine the percentage of coarse fragments. The particle size class was determined by the field method for all the sites except the sites selected for vegetation analysis, for which the particle size was determined by International Pipette Method (USDA Handbook, 1966).

The pH of the samples was determined by Soil Water Suspension (Jackson, 1973).

Stoniness refers to the relative proportion of stones over 10 inches in diameter in or on the soil (USDA Handbook, 1966). On the basis of the distinction done by USDA (1966) between different stoniness classes, the area allotted to each mine for mining was surveyed to determine the stoniness class.

The general slope of the area was determined by Abney's level.

The following standard range of soil reaction, stoniness class, particle size class and slope class as given by USDA for mine spoil classification (Juyal *et al.* 1995) were used for further analysis.

**a) Reaction Class**

| | |
|---|---|
| Alkaline and Calcareous | pH above 7.3 |
| Medium Acid to Alkaline | pH 5.6 – 7.3 |
| Acid | pH 3.6 – 5.5 |
| Extremely Acid | pH below 3.6 |

**b) Stoniness Class**

| **Class** | **Stones (%)** | **Tillage Potential** |
|---|---|---|
| Non-stony | < 0.01 | Can be tilled. |

| | | |
|---|---|---|
| Stony | 0.01 – 15 | Tillage limited can be mowed for hay, pasture etc. |
| Very stony | 15 – 50 | Treat by hand. |
| Extremely stony | > 50 | Unsuited. |

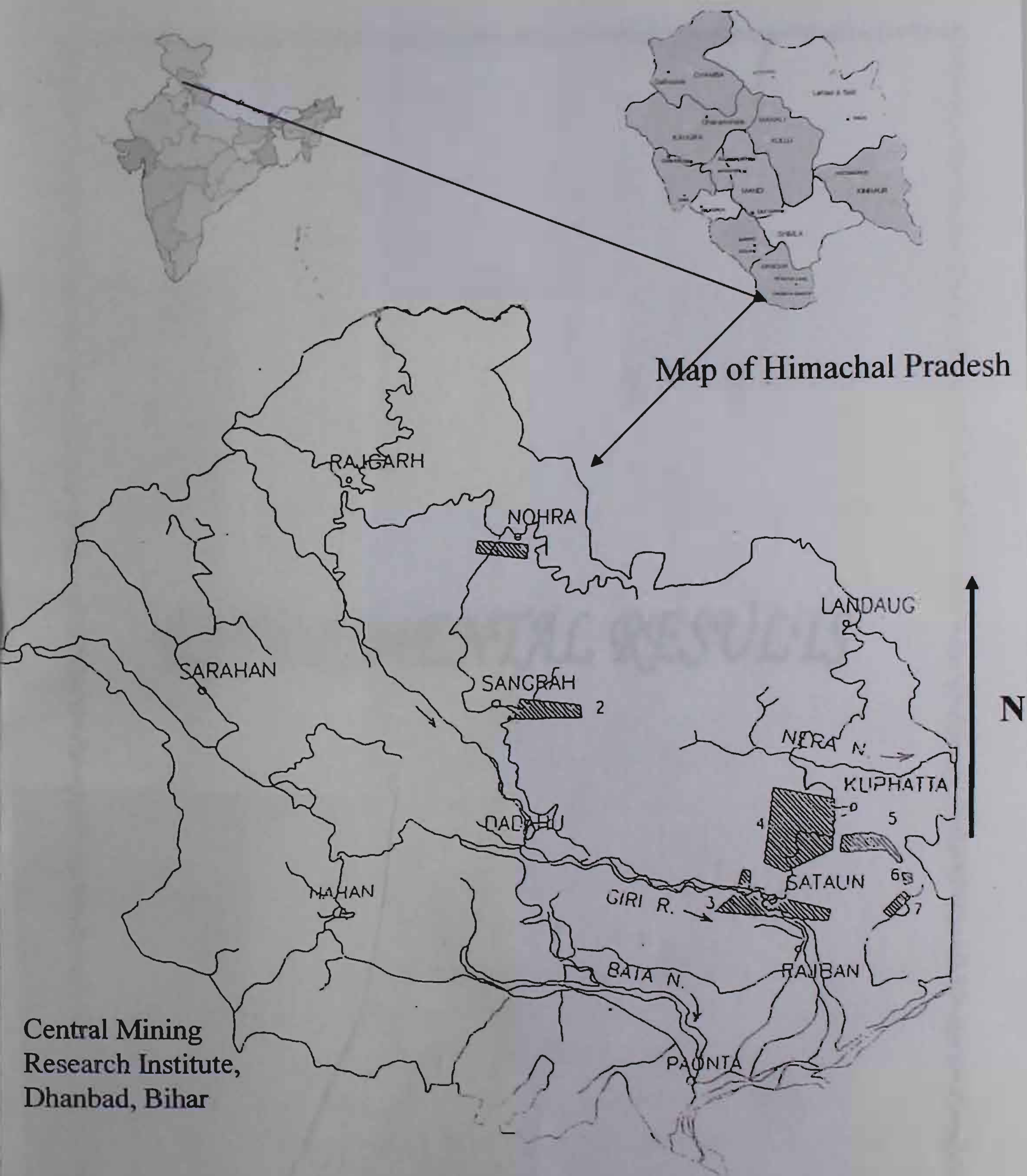
c) **Particle Size Class**

| | | |
|---|---|---|
| Fragmental | - | Mostly coarse fragments (pebbles, cobbles, stones and boulders) <10% fine earth (2mm or less). |
| Skeltal | - | 35 to 90% coarse fragments, 10 - 65% fine earth of which less than 18% is clay. |
| Sandy | - | < 35% coarse fragments, fine earth includes sandy and loamy sands, exclusive of loamy very fine sand or very fine sand. |
| Loamy | - | < 35% coarse fragments, fine earth includes loamy very fine sand, very fine sand and fine texture with less than 35% clay. |
| Clayey | - | < 35% coarse fragments, fine earth 35% or more clay. |

d) **Slope Classes**

| Slope Classes | Slope (%) |
|---|---|
| Nearly level to moderately steep | 0-30 |
| Steep | 30- 70 |
| Very steep | Over 70 |

The classes in which the mines fall were determined to classify the condition of mined area.




**Map of Sirmaur showing the study area**

# EXPERIMENTAL RESULTS

# CHAPTER-IV
# EXPERIMENTAL RESULTS

The results of the present investigation are presented in this chapter under the following heads:

**4.1** Survey of mined areas of district Sirmaur

**4.2** Change in vegetation patterns

**4.3** Comparison of physio-chemical characteristics of soil in mined and mine free areas.

## 4.1 Survey of mined areas of district Sirmaur

During the survey in March-April 2005 each mine was visited and the data recorded for the extent of mining, socio-economic status, dependence of people on mines and effects of mining on the environment etc. is presented below:-

### 4.1.1 Extent and status of mining

In Rajpura 11 limestone mines were recorded (Table 1). The period of the lease allotted to the mines in this section varied from 3 to 20 years. Total area under the limestone mines in Rajpura is 2104.70 bighas (156.17 ha). Till date 3.64 per cent (76.50 bighas) of area of the mines is under active mining. Four mines are closed permanently and rest are working. In Sangrah 15 limestone mines covering 1889.33 bighas (140.18 ha) were recorded. Maximum lease period allotted to these mines in this section was 20 years and minimum 5 years (Table 1). Active mine area is only 6.51 per cent (123.10 bighas) of the total area allotted for mining in this section. Only 5 mines are operational, rests have been closed temporarily or permanently. Sataun has majority of the limestone mines. The lease period varied from 5 to 40 years. Out of the total area (3063.46 bighas) allotted for mining, only 13.97 per cent (428.19 bighas) of the area is under active mining. The number of mines operational in this section is 22.

The list of the authorized stone crushers operating in district Sirmaur is presented in Table 2. The perusal of this Table reveals that permits for installation have been granted to 6 stone crushers in this district, out of which 2 are yet to be installed. The area allotted to stone crushers ranged from 5.00 – 110.75 bighas and the lease period allotted to each crusher owner is 5 years. Some areas are also granted on short term permits for sand extraction. The areas allotted to different lessee ranged from 19.15 to 238.5 bighas and for one year lease period. Though, 5 permits were granted for sand extraction but the information of only 4 could be procured. Sand is extracted from private lands. During, the survey it was also observed that there are many mines which are extracting limestone, sand, bajri and stones without any liason with the Department of Industries, H.P. Four such limestone mines are operating near Renuka extracting mineral from 2-3 hectares. Besides this, 6 sand mines (10-12ha), 6 bajri and stone mines (70-80 ha), 4 bajri and stone mines (60-70 ha), one sand mine (2-3 ha) and bajri mine (7-8 ha) are present in Chauri, Sarsoo, Banard and Zehar, respectively in Tehsil Pachad. An abandoned gold mine is also reported to be present just outside the university campus, Nauni.

### 4.1.2 Classification of the mined areas

The areas allotted for mining were classified into various classes as given by USDA. Table 3 reveals that all the limestone mines recorded in this district fall under 6 USDA classes. In Rajpura mines were classified as 1133 (Alkaline and calcareous, Non-stony, Sandy and Very steep) and 1143 (Alkaline and calcareous, Non-stony, Loamy and Very steep). In Sangrah 4 USDA classes of mines were recognized. Most of the mines in this section were falling in 1133 USDA class. Four USDA classes in Sataun were recorded. Thirty mines out of total 45 belonged to class 1133. Others were classified under classes 2233, 1143 and 1243.

**Table1:**
**Detail of limestone mines in district Sirmaur (H.P)**

| S.No. | Name | Year in which lease was granted | Year in which lease expires/ expired | Area leased for mining (Bighas) | Active mined area in leased out area (Bighas) | Present condition of mine |
|---|---|---|---|---|---|---|
| | **RAJPURA** | | | | | |
| 1. | Sh.Sant Ram | 23-07-1996 | 22-07-2001 | 34.04 | 2.05 | Closed |
| 2. | Sh. S. Bharti | 28-04-1987 | 16-02-2007 | 106.15 | 4.10 | Closed |
| 3. | M/s Agya Ram & Sons | 20-11-1964 | 24-4-1984 | 241.61 | 5.20 | Closed |
| 4. | Sh. Subhash Chand Chawla (Rudana) | 15-02-1986 | 14-03-2006 | 36.35 | 3.30 | Working |
| 5. | Sh. Subhash Chand Chawla (Bharli ) | 18-05-1992 | 17-05-2002 | 34.50 | 3.10 | Working |
| 6. | Sh. Subhash Chand Chawla (Banore ) | 02-06-1989 | 28-09-2009 | 349.65 | 15.40 | Working |
| 7. | Sh. Subhash Chand Chawla | 14-08-1984 | 13-08-2004 | 874.70 | 26.60 | Working |
| 8. | M/s Namrata Minerals & Chemicals | 16-06-1984 | 02-02-2004 | 100.00 | 5.50 | Working |
| 9. | Sh.Man Chand Goel | 25-05-1992 | 25-05-2002 | 274.20 | 6.40 | Working |
| 10. | Sh. Chattar Singh Tomar (Banore) | 03-04-1997 | 02-10-2000 | 8.45 | 2.35 | Closed |
| 11. | M/s Sher Singh Thakur | 22-04-1985 | 24-04-2005 | 45.05 | 2.50 | Working |
| | **SANGRAH** | | | | | |
| 12. | M/S Kapoor & Company | 03-12-1992 | 02-12-2012 | 57.00 | 10.60 | T.C* |
| 13. | M/s Nohra Mine & Minerals | 27-07-1992 | 26-09-2012 | 57.05 | 4.15 | T.C |
| 14. | Sh. Roop Singh Chauhan | 18-03-1993 | 17-03-2003 | 100.60 | 2.35 | T.C |
| 15. | Sh.Ratan Singh Panwar | 03-09-1992 | 02-09-1998 | 30.10 | 4.40 | Closed |
| 16. | Sh. V.K.Walia | 25-04-1985 | 24-04-2005 | 386.35 | 26.50 | Working |
| 17. | Sh. Sant Ram | 12-11-1993 | 11-11-1998 | 19.25 | — | Closed |
| 18. | Sh. Sunder Singh | 03-08-1990 | 02-08-2000 | 24.40 | 4.35 | Working |
| 19. | Sh.Sanjay Parmar | 17-06-1994 | 16-06-1999 | 14.10 | 5.40 | Closed |
| 20. | M/s Ahuja Plastic Pvt. Ltd. | 18-04-1984 | 17-04-2004 | 101.53 | 11.70 | Closed |
| 21. | Smt.Geeta Kumari | 05-10-1996 | 04-10-2006 | 30.10 | 4.40 | Working |
| 22. | M/s Gupta Associates | 21-12-1983 | 20-12-2003 | 192.85 | 15.40 | Working |
| 23. | Sh. V.K. Walia | 27-05-1992 | 26-05-2002 | 454.15 | 12.10 | Working |
| 24. | Kanwar Mirgender Singh | 20-04-1984 | 19-04-2004 | 93.00 | 1.00 | T.C |
| 25. | Sh. Chaman Lal Aggarwal | 06-01-1984 | 05-01-2004 | 240.35 | 3.00 | T.C |
| 26. | Sh. V.K.Walia (Raicha) | 13-01-1984 | 12-01-2004 | 88.50 | 16.75 | T.C |
| | **SATAUN** | | | | | |
| 27. | Sh.Chuhi Ram Sharma | 07-08-1992 | 06-08-2012 | 36.25 | 9.10 | T.C |
| 28. | Sh. Kush Parmar | 27-08-1981 | 26-08-2011 | 37.50 | 9.25 | Working |
| 29. | M/s Jyoti Mines & Minerals | 30-08-1993 | 29-08-1998 | 8.15 | 1.35 | Closed |
| 30. | Smt.Satya Tomar | 07-07-1984 | 06-07-2004 | 105.90 | 8.10 | Working |
| 31. | Sh.Sohan Singh Meet Singh | 18-04-1984 | 17-04-2004 | 54.70 | 6.05 | Working |
| 32. | M/s K.N.Cement | 14-03-1977 | 13-03-1997 | 290.95 | 8.60 | Working |
| 33. | Janki Devi | 27-07-1992 | 01-09-2022 | 66.20 | 7.60 | Working |
| 34. | Sh. Kanti Dogra | 24-08-1978 | 23-08-1998 | 185.00 | 7.75 | Closed |
| 35. | Sh.Padam Singh Chauhan | 24-07-1982 | 23-07-1992 | 50.00 | 11.80 | Closed |

Cont…

| | | | | | | |
|---|---|---|---|---|---|---|
| 36. | Sh.Nain Singh Sharma | 23-03-1996 | 22-03-2001 | 8.50 | 3.50 | Closed |
| 37. | Sh. Jalam Singh Fauji (Sh.Atma Ram) | 17-03-1987 | 16-03-1997 | 38.65 | 11.15 | Closed |
| 38. | Sh.Jank Raj Bansal | 27-05-2001 | 26-05-2021 | 21.15 | 6.14 | T.C |
| 39. | Sh. Chander Mohan Sharma | 02-02-2000 | 01-02-2005 | 18.20 | 5.40 | Working |
| 40. | C.C.I.Rajban | 30-10-1973 | 30-10-1993 | 225.30 | 70.00 | Working |
| 41. | M/s Giri Lime and Chemicals | 03-06-1985 | 02-06-2006 | 47.70 | 7.40 | T.C |
| 42. | Sh. Kahan Singh | 16-01-1993 | 15-01-1998 | 36.00 | 5.60 | T.C |
| 43. | Sh.K.K.Anand | 06-11-1963 | 05-11-2003 | 217.30 | 30.85 | Working |
| 44. | M/s Dharm Singh & Company | 02-03-1992 | 02-03-2002 | 32.20 | 5.30 | Closed |
| 45. | Sh. Yashwardhan Chauhan | 25-06-1985 | 24-06-2005 | 23.75 | 4.05 | T.C |
| 46. | Smt.Viplav Thakur | 20-07-1988 | 19-07-2007 | 105.90 | 8.15 | T.C |
| 47. | M/s R.P.Anand & Sons | 13-10-1967 | 12-10-1997 | 179.05 | 12.25 | Working |
| 48. | M/s Jhakhra Mines & Minerals | 19-03-1987 | 18-03-2007 | 105.75 | 13.55 | Working |
| 49. | Sh. Shanti Swaroop Dhiman | 03-10-1991 | 07-01-2001 | 29.05 | 5.60 | Working |
| 50. | Sh. Khajan Singh Sharma | 24-04-1998 | 23-04-2003 | 7.30 | 1.05 | Closed |
| 51. | M/S kamraoo Minerals | 09-01-1990 | 28-01-1995 | 10.90 | 2.20 | Working |
| 52. | M/S Himachal Mine & Quarries | 13-10-1967 | 12-10-1997 | 341.80 | 14.30 | T.C |
| 53. | M/s Barwas Mine | 22-04-1985 | 21-04-2005 | 88.45 | 8.05 | Working |
| 54. | Sh. Chatar Singh Tomar | 11-05-1999 | 07-04-2004 | 22.80 | 4.15 | Working |
| 55. | **Sh. Fateh Singh Tomar** | **06-08-1994** | **05-08-2004** | 15.20 | 2.15 | **Working** |
| 56. | Sh. Jalam Singh Fauji | 24-02-1995 | 23-02-2000 | 26.80 | 3.20 | Working |
| 57. | Sh.Jitender Prakash | 12-12-2001 | 11-12-2021 | 58.40 | 5.10 | T.C |
| 58. | M/s Balbir Singh Supa Ram | 02-09-2002 | 01-09-2022 | 10.00 | 2.05 | T.C |
| 59. | M/s Jai Singh Thakur & Sons (Baldwa) | 25-04-1985 | 24-04-2005 | 146.65 | 5.50 | Working |
| 60. | Sh. Layak Ram | 04-05-1983 | 16-10-2005 | 4.00 | 1.00 | T.C |
| 61. | M/s Balbir Singh Chauhan | 24-05-1983 | 05-09-1996 | 14.95 | 3.40 | Closed |
| 62. | M/s Mehar Singh Liak Ram | 24-11-1984 | 23-11-2004 | 27.20 | 3.35 | T.C |
| 63. | M/s Dharam Singh Mohar Singh | 17-05-1982 | 16-05-2005 | 24.20 | 2.50 | Working |
| 64. | M/s Dean & Company | 20-09-1977 | 19-09-1997 | 53.15 | 4.65 | T.C* |
| 65. | Smt. Savita Chauhan | 16-06-1986 | 15-06-2006 | 37.70 | 5.50 | Working |
| 66. | M/s Friends Minerals | 01-08-1985 | 31-07-2005 | 65.30 | 7.65 | Working |
| 67. | Sh. Inder Singh | 07-03-1996 | 06-03-2001 | 46.55 | 3.40 | Closed |
| 68. | M/s Jai Singh Thakur & Sons (Bohar) | 19-11-1985 | 24-06-2005 | 49.66 | 12.50 | Working |
| 69. | Sh. Anil Mohil Chattar Singh | 30-05-1987 | 29-05-2007 | 45.05 | 2.00 | T.C |
| 70. | Sh. Rakesh Chaudary | 20-03-2001 | 19-03-2031 | 39.25 | 2.05 | Working |
| 71. | Sh. Khajjan Singh Sharma | 24-04-1998 | 23-04-2003 | 5.20 | 1.00 | Closed |

*T.C= Temporary Closure

**Table 2:**
**Details of bajri/stone crushers and sand extraction in Sirmaur (H.P)**

| S. No. | Name | Place | Year in which lease was granted | Year in which lease expires/ expired | Area leased (Bighas) | Source of raw material | Present condition |
|---|---|---|---|---|---|---|---|
| **BAJRI / STONE CRUSHERS** | | | | | | | |
| 1. | Tribuvan stone crusher | Bankaka (Nahan) | 27-10-2002 | 26-10-2007 | 41.00 | Markanda river (Pvt.land) | Working |
| 2. | Ashish stone crusher | Bangran (Poanta Sahib) | 28-09-2000 | 27-09-2005 | 110.75 | Giri river (Pvt.land) | Working |
| 3. | Akhilesh enterprises | Ganguwala (Poanta Sahib) | 22-08-2000 | 21-08-2005 | 10.00 | Yamuna river (Pvt.land) | Working |
| 4. | Rock lime and allied products | Rampurghat (Poanta Sahib) | 03-10-2000 | 02-10-2005 | 05.00 | Confluence of Giri & Yamuna river (Pvt.land) | Working |
| 5. | Shubhlata Sharma | Rampurghat (Poanta Sahib) | 22-11-2003 | 21-11-2008 | 13.90 | Giri river (Pvt.land) | Yet to be installed |
| 6. | Reeta Sharma | Yashwant Nagar (Rajgarh) | 22-11-2003 | 21-11-2008 | 30.80 | Giri river (Govt.land) | Yet to be installed |
| **SAND EXTRACTION** | | | | | | | |
| 7. | Inder Singh and Co. | Mohkampur (Poanta Sahib) | 28-10-2004 | 27-10-2005 | 238.50 | Part of Giri river (Pvt.land) | Working |
| 8. | Lalit Kumar Jang | Ganguwala (Poanta Sahib) | 23-10-2004 | 22-10-2005 | 24.00 | Part of Yamuna river (Pvt.land) | Working |
| 9. | Farm Fresh Food | Bhatanwali (Poanta Sahib) | 18-10-2004 | 17-10-2005 | 19.15 | Part of Yamuna river (Pvt.land) | Working |
| 10. | Imtiaz Ahmad | Bharanpur (Poanta Sahib) | 21-10-2004 | 19-10-2005 | 28.45 | Part of Yamuna river (Pvt.land) | Working |
| 11. | Kamal Gupta | | | | | | |

**Table 3:**
**Classification for limestone mine soils of district Sirmour (H.P.)**

| Sr. no. of mine in table (1) | USDA symbols for mine soil classification | pH | Stoniness | Particle Size class | Slope (%) |
|---|---|---|---|---|---|
| | | **RAJPURA** | | | |
| 4,5,7,8,9 | (1133) | 7.75-7.94 (Alkaline and calcareous) | Non-Stony* | 66.38-72.32 % fine earth (Sandy) | 75.60-84.40 (Very steep) |
| 1,2,3,6,10,11 | (1143) | 7.70-7.86 (Alkaline and calcareous) | Non-Stony | 66.22-73.12 % fine earth (Loamy) | 78.40-82.50 (Very steep) |
| | | **SANGRAH** | | | |
| 12,13,14 | (1132) | 7.59-7.84 (Alkaline and calcareous) | Non-Stony | 69.99-79.74 % fine earth (Sandy) | 43.70-56.20 (Steep) |
| 15,16,17,18,19,24,26 | (1133) | 7.66-8.20 (Alkaline and calcareous) | Non-Stony | 65.42-75.64 % fine earth (Sandy) | 72.40-79.60 (Very steep) |
| 22,23,25 | (1233) | 7.73-8.29 (Alkaline and calcareous) | Stony** | 69.20-75.68 % fine earth (Sandy) | 74.70-78.60 Very steep) |
| 20,21 | (1143) | 7.68-8.04 (Alkaline and calcareous) | Non-Stony | 65.42-70.62 % fine earth (Loamy) | 73.50-80.20 (Very steep) |
| | | **SATAUN** | | | |
| 29,30,31,32,33,34,36,37, 39,41,42,43,44,45,47,48, 50,51,53,56,57,58,59,60, 62,64,65,68,69,71 | (1133) | 7.54-8.10 (Alkaline and calcareous) | Non-Stony | 65.70`-77.68 % fine earth (Sandy) | 75.60-86.90 (Very steep) |
| 40 | (2233) | 6.36-6.48 (Medium acid to alkaline) | Stony | 69.48-73.41 % fine earth (Sandy) | 74.30-82.60 (Very steep) |
| 27,28,35,38,49,54,55,61, 63,66,67 | (1143) | 7.83-8.10 (Alkaline and calcareous) | Non-Stony | 67.48-76.32 % fine earth (Loamy) | 76.30-87.10 (Very steep) |
| 46,52,70 | (1243) | 7.79-7.96 (Alkaline and calcareous) | Stony | 67.44-73.62 % fine earth (Loamy) | 77.60-82.30 (Very steep) |

*Non-Stony = (<0.01%) of the area occupied by stones over 10 inches in diameter.
**Stony = (0.01 to 15 %) of the area occupied by stones over 10 inches in diameter.

### 4.1.3 Socio-economic studies

A perusal of data in Table 4 reveals that on an overall basis the average number of males and females in a family in the mined areas of district Sirmaur was 6.17 and 5.06, respectively. The maximum number (6.61) of males in a family was recorded in Rajpura whereas; the maximum number (5.67) of females in a family was in Sataun. In general, females were less than males in a family in the mined areas of district Sirmaur. Inquisition of data further, showed that the number of children/infants was more than 50 per cent of the number of the adults in the 15-45 years age group. Majority of the males and females in the area were in the age group of 15-45 years. On an average, in a family the males and females in age group of 15-45 years were represented by 51.76 per cent and 49.57 per cent, respectively. The persons beyond 45 years were least among different age classes.

An appraisal of the data in the Table 5 reveals that the literacy in the mined areas of district Sirmaur on an average was 57.25 per cent. Out of this, 20.87 per cent has education upto primary, 13.87 per cent upto middle, 9.76 per cent upto matriculation, 6.07 per cent upto higher secondary and 6.68 per cent are graduates and above. The maximum literacy rate (61.71 per cent) was recorded in Rajpura followed by Sataun (55.49 per cent) and Sangrah (54.55 per cent). Though all the sections differed slightly in the literacy but Rajpura had higher (8.71 per cent) proportion of graduates and above.

During survey, data on the profession of people in the mined areas of district Sirmaur revealed multiple response. People in this region are primarily agrarian by profession; dependent upon agriculture (Table 6). Besides it, people are employed with government and private entrepreneurs. In Rajpura per cent of families employed in government jobs was strikingly high (50.00 per cent) as compared to Sangrah (20.00 per cent) and Sataun (13.33 per cent). Conversely, people engaged in mining for earnings were comparatively higher in Sataun (50.00 per cent) and Sangrah (40.00 per cent) as compared to Rajpura (36.66 per cent). It is evident that more people were dependent upon mines in Sataun and Sangrah, especially Sataun. On an average, in mined areas of district Sirmaur 27.77 per cent adults were earning through government employment and 42.22 per cent were closely linked with mines (Table 6). Other professions like rural artisans, shop keeping and others (local labour, contractors etc.) provided earnings to good proportion of families living here.

The distribution of families in the mined areas of district Sirmaur in accordance to annual family income is shown in Table 7. It is seen from the Table that on an average the majority (58.89 per cent) of the families were having annual income range of Rs 0.5 – 1 lakh. A good number (28.88 per cent) of families were also falling in the annual income group of more than Rs. 1 lakh whereas 12.23 per cent of the families were falling in the low-income group of Rs. less than 0.5 lakh annually. The results further reveal that in the income group of Rs 0.5 – 1 lakh, maximum (70.00 per cent) families were found in Sataun followed by Sangrah (56.67 per cent) and Rajpura (50.00 per cent). Likewise, in Rajpura 43.33 per cent families were earning more than 1 lakh rupees annually followed by Sangrah (26.66 per cent) and Sataun (16.66 per cent).

Table 8 shows the time period and the proportion of the families engaged in mines. It is seen from the Table that on an overall basis 42.22 per cent of the families were engaged in mines, out of which 88.89 per cent were employed in mines for more than 5 years. In Rajpura and Sataun all the persons are employed in mines for more than 5 years. However, in Sangrah section only 66.67 per cent of the families are working in mines for more than 5 years (Table 8). It can further be appraised from the Table that only 36.66 per cent to 50.00 per cent of families of the mining area opt to get employment in mines. Rest seeks other professions for earning.

Mining as a primary or subsidiary source of income of the people in the mined areas of district Sirmaur depicted that 36.66 per cent of the workers had mining as their main source of income, whereas, 63.64 per cent were earning mainly from other sources, thus mining was their subsidiary source of income (Table 9). Scrutiny of the data further explicated that maximum proportion of the workers (60.00 per cent) in Sataun has mining

**Table 4:**
**Average family size and male/ female per cent in a family around limestone mines in district Sirmaur (H.P.)**

| Section | Average family size (Number) | | | Male Age in years | | | Female Age in years | | |
|---|---|---|---|---|---|---|---|---|---|
| | Male | Female | Total | 0-15 | 15-45 | >45 | 0-15 | 15-45 | >45 |
| Rajpura | 6.61 | 5.36 | 11.97 | 23.75 | 56.58 | 19.67 | 33.03 | 52.80 | 14.17 |
| Sangrah | 5.36 | 4.16 | 9.52 | 37.32 | 46.64 | 16.04 | 32.93 | 49.52 | 17.55 |
| Sataun | 6.53 | 5.67 | 12.20 | 29.55 | 52.06 | 18.39 | 32.98 | 46.38 | 20.64 |
| Average | 6.17 | 5.06 | 11.23 | 30.21 | 51.76 | 18.03 | 32.98 | 49.57 | 17.45 |

**Table 5:**
**Education level of people in the limestone mine areas of district Sirmaur (H.P.)**

**(Per cent)**

| Section | Illiterate | Literate | | | | |
|---|---|---|---|---|---|---|
| | | Upto Primary | Upto Middle | Upto Matriculation | 10+2/Diploma | Graduate and above |
| Rajpura | 38.29 | 24.63 | 13.31 | 10.45 | 4.61 | 8.71 |
| Sangrah | 45.45 | 19.95 | 13.30 | 8.43 | 6.21 | 6.66 |
| Sataun | 44.51 | 18.03 | 15.00 | 10.41 | 7.38 | 4.67 |
| Average | 42.75 | 20.87 | 13.87 | 9.76 | 6.07 | 6.68 |

**Table 6:**
**Profession of families in the limestone mine areas of district Sirmaur (H.P.)**

**(Multiple response)** **(Percent)**

| Section | Occupation | | | | | |
|---|---|---|---|---|---|---|
| | Agriculture | Govt. service | Rural Artisans | Shopkeeper | Mining | Others |
| Rajpura | 100.00 | 50.00 | 0.00 | 3.33 | 36.66 | 30.00 |
| Sangrah | 100.00 | 20.00 | 3.33 | 26.66 | 40.00 | 33.33 |
| Sataun | 100.00 | 13.33 | 0.00 | 16.67 | 50.00 | 20.00 |
| Average | 100.00 | 27.77 | 1.11 | 15.55 | 42.22 | 27.77 |

**Table 7:**
**Annual income of families (%) in limestone mine areas of district Sirmaur (H.P.)**

| Section | Annual income (Rs.) | | |
|---|---|---|---|
| | <0.50 lakh | 0.50 - 1.0 lakh | >1.0 lakh |
| Rajpura | 6.67 | 50.00 | 43.33 |
| Sangrah | 16.67 | 56.67 | 26.66 |
| Sataun | 13.34 | 70.00 | 16.66 |
| Average | 12.23 | 58.89 | 28.88 |

**Table 8:**
**Family employment (%) in mines in the limestone mine areas of district Sirmaur (H.P)**

| Section | Employed in mines | Not employed in mines | Number of years engaged in mining | |
|---|---|---|---|---|
| | | | < 5 | > 5 |
| Rajpura | 36.66 | 63.34 | 0.00 | 100.00 |
| Sangrah | 40.00 | 60.00 | 33.33 | 66.67 |
| Sataun | 50.00 | 50.00 | 0.00 | 100.00 |
| Average | 42.22 | 57.78 | 11.11 | 88.89 |

**Table 9:**
**Monthly income range of workers from limestone mines in the district Sirmaur (H.P.)**

| Section | Mining as a source of income (%) | | Per capita income of persons working in mines (Rs.) |
|---|---|---|---|
| | Main | Subsidary | |
| Rajpura | 0.00 | 100.00 | 866.67 – 1033.33 |
| Sangrah | 50.00 | 50.00 | 1330.76 – 1707.76 |
| Sataun | 60.00 | 40.00 | 1723.33 – 1990.00 |
| Average | 36.66 | 63.34 | 1306.92 – 1577.03 |

as their main source of income; however, in Rajpura no person was recorded to be fully dependent on the mines for his livelihood. Study was also made to apprise the range of income earned from mines by people in different mining sections of the district Sirmaur. The range of income per person per month from mining was maximum (Rs.1723.33 – 1990.00) in Sataun followed by Sangrah (Rs.1330.76 – 1707.76) and Rajpura (Rs. 866.67 – 1033.33) (Table 9). On an average, income from mining per person per month was in the range of Rs.1306.92 – 1577.03.

The affect of mining on the total income of the population in the mined areas of the district Sirmaur is presented in Table 10. The data reveals that on an average 40.00 per cent of the people improved their earnings on account of existence of mines. Increase in income was reported by 36.67 per cent to 46.67 per cent of the people living in different sections of mined area with maximum in Sataun (Table 10). It was recorded that there was no decrease in income of people in Rajpura and Sangrah sections of district Sirmaur on account of mining activities. However, in Sataun section 6.66 per cent people complained decrease in income due to mines. On an average, 57.78 per cent of the people in mined areas reported no change in their income.

A critical look on the Table 11 illustrated that the average land holding possessed by a family in the mined areas of district Sirmaur was 13.41 bighas. The land holding per family was maximum (16.28 bighas) in Sangrah followed by 12.45 bighas in Sataun and 11.50 bighas in Rajpura. Irrigated land constituted 16.96 per cent of the total land holding in mining areas of district Sirmaur. Maximum (24.75 per cent) proportion of irrigated land was recorded in Sangrah followed by Sataun and Rajpura, with 15.63 per cent and 10.67 per cent irrigated land, respectively. It was further recorded that on an average the majority (88.88 per cent) of the families in the mined area has no ownership in the mining lands. The maximum proportion of families with ownership rights in mining land was found in Sataun (23.34 per cent) followed by Sangrah (6.67 per cent) and Rajpura (3.33 per cent).

The people working in the mines disclosed many problems, like low wages, low royalty and periodic closure of mines, to continue mines as a source of income (Table 12). The result explicates that on an overall basis low wages given to workers in mines casts aspersions in their minds to continue mines as source of income. As high as 58.33 per cent people in Sangrah, 46.66 per cent in Sataun and 27.77 per cent in Rajpura were facing low wages problem in mines. Low royalty being extended to people, having property rights in mines, by mine owners was another reason that people are not willing to continue mines as their source of income. In Sataun 23.34 per cent people were having ownership rights and all reported low royalty is being paid to them against their land. The periodic closure of mines was another problem for (8.28 per cent on average, 6.70 per cent to 18.18 per cent in different sections) people living here to continue mines as a source of income.

As regard the problems mentioned above, people proposed possible solutions which are increased salary, increased royalty, uninterrupted mining and continuous interaction of officials-workers and mine owner's (Table 13). The increase in wages was suggested by (44.08 per cent on average, 27.27-58.33 per cent in different sections) of people living in the mined areas. The increase in royalty was favoured by 23.34 per cent of people in Sangrah only. Uninterrupted mining was suggested by 28.55 per cent of the people on an overall basis (Table 13). Continuous interaction of officials-workers and mine owner's for safe-guarding the interests of the people was suggested by 20.00 per cent persons in Sataun only.

Study was made to assess the ecological impact of mining in mined areas of district Sirmaur (Table 14). Decrease in natural sources of water was reported by 70.00 per cent of the people. The percentage was maximum (73.33 per cent) in Sataun followed by Sangrah (70.00 per cent) and Rajpura (66.67 per cent). The breakage of water channels (kuhls) was however reported by 80.00 per cent of the people in Rajpura followed by 60.00 per cent in Sataun and 40.00 per cent in Sangrah. Water pollution was reported by 10.00 per cent of the population living in mined areas district Sirmaur.

**Table 10:**
**People's opinion (%) for change in income on account of mines in limestone mine areas of district Sirmaur (H.P.)**

| Section | Increase | Decrease | No Change |
|---|---|---|---|
| Rajpura | 36.67 | 0.00 | 63.33 |
| Sangrah | 36.67 | 0.00 | 63.33 |
| Sataun | 46.67 | 6.66 | 46.67 |
| Average | 40.00 | 2.22 | 57.78 |

**Table 11:**
**Average land holding and ownership in mines of the families in the limestone mine areas of district Sirmaur (H.P.)**

| Section | Average landholdings (Bighas) | Irrigated (%) | Unirrigated (%) | With ownership in mines (%) | Without ownership in mines (%) |
|---|---|---|---|---|---|
| Rajpura | 11.50 | 10.67 | 89.33 | 3.33 | 96.67 |
| Sangrah | 16.28 | 24.57 | 75.43 | 6.67 | 93.33 |
| Sataun | 12.45 | 15.63 | 84.37 | 23.34 | 76.66 |
| Average | 13.41 | 16.96 | 83.04 | 11.12 | 88.88 |

**Table 12:**
**People's (%) opinion for continuing mines as a source of income in limestone mine areas of district Sirmaur (H.P.)**

**(Multiple response)**

| Section | Problems faced in mining as a source of income | | |
|---|---|---|---|
| | Low wages | Royalty low | Periodic closure of mines |
| Rajpura | 27.27 | 0.00 | 18.18 |
| Sangrah | 58.33 | 0.00 | 0.00 |
| Sataun | 46.66 | 23.34 | 6.66 |
| Average | 44.08 | 7.78 | 8.28 |

**Table 13:**
**Proposed solutions by people (%) to the problems in continuing mines as a primary source of income in the limestone mine areas of district Sirmaur (H.P.)**

**(Multiple response)**

| Section | Solutions to the problems | | | |
|---|---|---|---|---|
| | Increase in wages | Increase in royalty | Uninterrupted mining | Continuous interaction of officials, workers and mine owner's |
| Rajpura | 27.27 | 0.00 | 27.27 | 0.00 |
| Sangrah | 58.33 | 0.00 | 25.00 | 0.00 |
| Sataun | 46.66 | 23.34 | 33.33 | 20.00 |
| Average | 44.08 | 7.78 | 28.55 | 6.67 |

Table 14:
**People's response (%) to ecological impacts of mining on water, agriculture, pollution, flora, fauna, and other natural resources of district Sirmaur (H.P.)**

| FACTORS | | EFFECTS | Rajpura section | Sangrah section | Sataun section | Average |
|---|---|---|---|---|---|---|
| Water | Decrease in natural sources | Decrease | 66.67 | 70.00 | 73.33 | 70.00 |
| | | No change | 33.33 | 30.00 | 26.67 | 30.00 |
| | Breakage of water channels | Occurred | 80.00 | 40.00 | 60.00 | 60.00 |
| | | Not occurred | 20.00 | 60.00 | 40.00 | 40.00 |
| | Pollution | Occurred | 10.00 | 10.00 | 10.00 | 10.00 |
| | | Not occurred | 90.00 | 90.00 | 90.00 | 90.00 |
| Agriculture | Productivity | Decrease | 0.00 | 0.00 | 3.33 | 1.11 |
| | | No change | 100.00 | 100.00 | 96.67 | 98.89 |
| | Erosion of agricultural lands | Occurred | 100.00 | 73.33 | 80.00 | 84.44 |
| | | Not occurred | 0.00 | 26.67 | 20.00 | 15.56 |
| | Cropping Pattern | No Change | 100.00 | 100.00 | 100.00 | 100.00 |
| Blockage of roads | | Occurred | 0.00 | 0.00 | 10.00 | 3.33 |
| | | Not occurred | 100.00 | 100.00 | 90.00 | 96.67 |
| Damage to houses | | Occurred | 10.00 | 16.66 | 16.66 | 14.44 |
| | | Not occurred | 90.00 | 83.34 | 83.34 | 85.56 |
| Fallow lands | | Increase | 100.00 | 100.00 | 100.00 | 100.00 |
| Dust pollution | | Increase | 100.00 | 100.00 | 100.00 | 100.00 |
| Noise pollution | | Increase | 100.00 | 100.00 | 100.00 | 100.00 |
| Fauna | | No Change | 100.00 | 100.00 | 100.00 | 100.00 |
| Flora | | No Change | 100.00 | 100.00 | 100.00 | 100.00 |

Most of the people living in the vicinity of mining area in district Sirmaur were of the opinion that there is no adverse impact of mining on agricultural production. However, around 3.33 per cent people in Sataun have observed fall in the agricultural production. Table 14 further reveals that majority (84.44 per cent on average, 80.00 per cent to 100.00 per cent in different sections) of the people reported erosion of agricultural lands. No change in cropping pattern, if any, was reported by people in all the sections of the study area on account of mining.

Inquisition of the data further explicated that the blockage of roads due to mining was observed by 10.00 per cent of the people in Sataun only. The damage to houses as a result of blasting in mines was reported by 16.66 per cent of the population in Sangrah and Sataun followed by 10.00 per cent in Rajpura (Table 14). The increase in fallow lands was reported by all the people of the study area. All the people of the study area have experienced rise in noise levels due to mining. The increase in dust pollution was also observed by all the people. All the people were of the view that there is no change in flora and fauna due to mining.

## 4.2 Change in vegetational patterns

Three types of vegetation viz. Moist Shiwalik Sal forest, Dry mixed deciduous forest and Quercus forest were recognized in the limestone mine areas during the survey which were further analyzed for vegetation composition and reclamation processes as given below:

Under Moist Shiwalik Sal forest three sites viz. (a) Undisturbed Sal forest (b) 6 years old abandoned mine site and (c) Reclaimed mine site (13 years old) revealed the following:

Undisturbed Sal forest (Plate 1) comprised of 3 trees, 8 shrubs and 8 herbs. 1165 trees/ha were recorded in this forest with their basal area as 7902.45 x $10^2$ $cm^2$/ha. *Shorea robusta* accounted for 88.66 per cent (1033 tees/ha) of the total density of trees.

Likewise, the basal area of *Shorea robusta* was 87.22 per cent (6892.49 x $10^2$ $cm^2$/ha) of the total basal area of trees. Thus, it was the dominant tree species. *Phoenix acaulis* and *Pyrus pashia* were the associate species with it (Table 15).

Total density of shrubs recorded on this site was 549.32 x $10^2$ stems/ha. Highest density was recorded for *Eupatorium reveesii* (248.00 x $10^2$ stems/ha) followed by *Boehmeria platyphylla* (125.32 x $10^2$ stems/ha) and *Adhatoda vasica* (70.68 x $10^2$ stems/ha). Lowest density was recorded for *Randia tetrasperma* (8.00 x $10^2$ stems/ha).Total basal area of shrubs was 2514.96 x $10^2$ $cm^2$/ha. Highest basal area was recorded for *Eupatorium reveesii* (1321.68 x $10^2$ $cm^2$/ha) followed by *Maesa chisia* (365.80 x $10^2$ $cm^2$/ha) and *Boehmeria platyphylla* (217.36 x $10^2$ $cm^2$/ha) whereas, lowest basal area was recorded for *Carissa spinarium* (51.92 x $10^2$ $cm^2$/ha). *Eupatorium reveesii* was the dominant shrub species with IVI as (119.12). *Boehmeria platyphylla* (45.73) and *Adhatoda vasica* (35.77) were co-dominant species. *Carissa spinarium, Maesa chisia, Murraya koenigii* and *Lantana camara* maintained almost similar IVI values as 21.68, 24.37, 23.44 and 19.14, respectively and were the associate species. *Randia tetrasperma* was the rare shrub species in this forest with IVI value of 10.75 (Table 15).

Total density of the herbaceous vegetation recorded on this site was 7717.00 x $10^2$ ind./ha Only one grass species (*Oplismenus compositus*) was recorded on this site which showed highest values of density (3900.00 x $10^2$ ind./ha.), basal area (361.00 x $10^2$ $cm^2$/ha) and IVI (104.36) among different herbs. The density of the forbs ranged from 250.00 x $10^2$ ind./ha to 850.00 x $10^2$ ind./ha. Total basal area of the herbaceous vegetation recorded on this site was 991.00 x $10^2$ $cm^2$/ha. The basal area of forbs ranged form 14.00 x $cm^2$/ha to 263.00 x $10^2$ $cm^2$/ha (Table 15). IVI values of the herbaceous vegetation indicated that *Oplismenus compositus* was the dominant species whereas, *Arisaema* spp. (42.23), *Dicliptera bupleuroides* (35.57) and *Carex setigera* (36.57) were the co-dominant species. *Blepharis maderaspatensis* (14.20), *Bidens pillosa* (22.27) and *Oxalis corniculata* (13.35) were the rare species.

**Table15:**
**Species composition of Sal forest in limestone mine area of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Trees** | | | | | | |
| *Phoenix acaulis* (Roxb.) | 0.66 | 0.66 | 989.36 | 989.36 | 0.33 | 38.19 |
| *Pyrus pashia* (Buch.-Ham.) | 0.66 | 0.66 | 20.60 | 20.60 | 0.33 | 25.93 |
| *Shorea robusta* (Gaertn.f.) | 10.33 | 10.33 | 6892.49 | 6892.49 | 1.00 | 235.88 |
| **Total** | **11.65** | **11.65** | **7902.45** | **7902.45** | | |
| **Shrubs** | | | | | | |
| *Adhatoda vasica* (Nees.) | 17.67 | 70.68 | 54.21 | 216.84 | 0.66 | 35.77 |
| *Boehmeria platyphylla* (Don.) | 31.33 | 125.32 | 54.34 | 217.36 | 0.66 | 45.73 |
| *Carissa spinarium* (Linn.) | 7.33 | 29.32 | 12.98 | 51.92 | 0.66 | 21.68 |
| *Eupatorium reveesii* (Wall.) | 62.00 | 248.00 | 330.42 | 1321.68 | 1.00 | 119.12 |
| *Lantana camara* (Linn.) | 9.33 | 37.32 | 32.58 | 130.32 | 0.33 | 19.14 |
| *Maesa chisia* (Buch.-Ham.ex D.Don) | 3.67 | 14.68 | 91.45 | 365.80 | 0.33 | 24.37 |
| *Murraya koenigii* (Spreng.) | 4.00 | 16.00 | 39.26 | 157.04 | 0.66 | 23.44 |
| *Randia tetrasperma* (Roxb.) | 2.00 | 8.00 | 13.50 | 54.00 | 0.33 | 10.75 |
| **Total** | **137.33** | **549.32** | **628.74** | **2514.96** | | |
| **Grasses/ Herbs** | | | | | | |
| *Oplismenus compositus* (Linn.) | 39.00 | 3900.00 | 3.61 | 361.00 | 0.66 | 104.36 |
| *Ariseama spp.* | 6.17 | 617.00 | 2.63 | 263.00 | 0.33 | 43.23 |
| *Bidens pillosa* (Linn.) | 5.33 | 533.00 | 0.23 | 23.00 | 0.50 | 22.27 |
| *Blepharis maderaspatensis* (Roth.) | 3.00 | 300.00 | 0.16 | 16.00 | 0.33 | 14.20 |
| *Dicliptera bupleuroides* (Nees.) | 7.50 | 750.00 | 1.27 | 127.00 | 0.50 | 35.57 |
| *Oxalis corniculata* (Linn.) | 2.50 | 250.00 | 0.14 | 14.00 | 0.33 | 13.35 |
| *Curculigo orchioides* (Gaert.) | 5.17 | 517.00 | 0.63 | 63.00 | 0.66 | 30.45 |
| *Carex setigera* (D.Don.) | 8.50 | 850.00 | 1.24 | 124.00 | 0.50 | 36.57 |
| **Total** | **77.17** | **7717.00** | **9.91** | **991.00** | | |

In abandoned site (6 years old) adjacent to the Sal forest (Plate 1) in the limestone mined area one tree, 2 shrubs and 4 herbs were recorded. *Wendlandia exserta*, the only tree recorded in this site exhibited stunted growth with average height of 2-3 ft. The density of this species was 200 trees/ha and basal area as 9.76 x $10^2$ $cm^2$/ha (Table 16).

*Eupatorium reveesii* dominated the shrubs as it accounted for 80.09 per cent (148.00 x $10^2$) ind/ha of the total population (168.00 x $10^2$ ind/ha) of shrubs. Like wise, 64.90 per cent (311.56 x $10^2$ $cm^2$/ha) of the total basal area (480.00 x $10^2$ $cm^2$/ha) of shrubs was represented by this species (Table 16).

Among herbaceous vegetation, grasses exhibited higher population of individuals compared to forbs in the total density (1232.00 x $10^2$ ind/ha). The forb, *Scutellaria grossa* exhibited highest density (384.00 x $10^2$ ind/ha) among different herbs. The density of two grasses viz., *Heteropogon contortus* and *Capillipedium heugelli* closely followed *Scutellaria grossa* with their respective densities as 310.00 x $10^2$ ind/ha and 340.00 x $10^2$ ind/ha. Lowest density (44.00 x $10^2$ ind/ha) was represented by *Rumex hastatus*. Forbs accounted for 74.85 per cent (99.40 x $10^2$ $cm^2$/ha) of the total basal area (132.80 x $10^2$ $cm^2$/ha) of herbs. *Rumex hastatus* achieved the highest (75.76 x $10^2$ $cm^2$/ha) basal area whereas, the lowest basal area (7.00 x $10^2$ $cm^2$/ha) was reported for *Chrysopogon montanus*. IVI values indicated that *Rumex hastatus* (82.84) and *Scutellaria grossa* (71.19) were the dominant species. *Heteropogon contortus* (57.38) and *Capillipedium heugelli* (59.70) were the co-dominant species whereas; *Chrysopogon montanus* (28.89) was the associate species (Table 16).

The reclaimed site (Plate 1), where *Shorea robusta* existed prior to mining, revealed 5 trees, 8 shrubs and 8 herbs (Table 17). 2300 trees/ha were recorded with their basal area as 1049.41 x $10^2$ $cm^2$/ha. Highest density was recorded for *Dalbergia sissoo* (8.00 x $10^2$ ind/ha), closely followed by *Wendlandia exserta* (6.67 x $10^2$ ind/ha), whereas, lowest density was recorded for *Pyrus pashia* (0.33 x $10^2$ ind/ha). Likewise, highest basal area was recorded for *Dalbergia sissoo* (363.20 x$10^2$ $cm^2$/ha) followed by *Wendlandia exserta* (337.60 x $10^2$ $cm^2$/ha). *Pyrus pashia* was found to have lowest basal area (2.31 x $10^2$ $cm^2$/ha). Comparison of the IVI values of different trees indicated that Dalbergia *sissoo* (99.39) and *Wendlandia exserta* (91.17) were the dominant species, whereas, *Acacia catechu* (57.00) and *Leuceana leucocephala* (40.78) were the co-dominant species. *Pyrus pashia* was a rare species in this type of vegetation with IVI value of 11.66 (Table 17).

Total density of the shrubs recorded on this site was 1708.52 x $10^2$ ind/ha. *Eupatorium reveesii* represented 70.57 per cent (1205.72 x $10^2$ stems/ha) of this density followed by *Lantana camara* (468.00 x $10^2$ stems/ha). All other species were found to have very low number of individuals. Highest basal area was recorded for *Lantana camara* (3512.16 x $10^2$ $cm^2$/ha) as against total basal area of shrubs (6324.12 x $10^2$ $cm^2$/ha), followed by *Eupatorium reveesii* (2178.76 x $10^2$ $cm^2$/ha). Lowest density (2.28 x $10^2$ stems/ha) and basal area (14.92 x $10^2$ $cm^2$/ha) was recorded for *Murraya koenigii*. IVI values of shrubs indicated that *Eupatorium reveesii* (136.83) and *Lantana camara* (110.19) were the dominant and co-dominant species respectively. All other species were rare in this type of vegetation.

Forbs exhibited higher population of individuals compared to grasses in the total density (21083.00 x $10^2$ ind/ha) of herbs. Forb, *Fimbristylis rigidula* exhibited highest density (10633.00 x $10^2$ ind/ha) among herbaceous vegetation. The density of the three grasses, *Saccharum spontaneum, Arundinella nepalensis* and *Digitaria stricta,* recorded on this site was comparatively low with their respective densities as 2600.00 x $10^2$ ind/ha, 1367.00 x $10^2$ ind/ha and 1267.00 x $10^2$ ind/ha. Least density among herbs was recorded for *Viola serpens* and *Pilea scripta* as (350.00 x $10^2$ ind/ha). Forbs accounted for 78.03 per cent (1549.00 x $10^2$ $cm^2$/ha) the total basal area (1985.00 x $10^2$ $cm^2$/ha) of herbs. *Fimbristylis rigidula* achieved the highest basal area of (829.00 x $10^2$ $cm^2$/ha) whereas, the lowest basal area was recorded for *Digitaria stricta* (22.00 x $10^2$ $cm^2$/ha). IVI value of the herbs indicated that *Fimbristylis rigidula* was the dominant species with IVI value of 112.20, whereas, *Saccharum spontaneum* and *Dicliptera bupleuroides* were the co-dominant species with their respective IVI values as 39.56 and 43.48 (Table 17).

**Table16:**
**Species composition of abandoned limestone mine site (6 years) in Sal forest of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Trees** | | | | | | |
| *Wendlandia exserta* (D.C.) | 0.50 | 2.00 | 2.44 | 9.76 | 0.50 | |
| **Shrubs** | | | | | | |
| *Boehmeria platyphylla* (Don.) | 5.00 | 20.00 | 42.11 | 168.44 | 0.50 | 80.01 |
| *Eupatorium reveesii* (Wall.) | 37.00 | 148.00 | 77.89 | 311.56 | 1.00 | 219.99 |
| **Total** | **42.00** | **168.00** | **120.00** | **480.00** | | |
| **Grasses/ Herbs** | | | | | | |
| *Chrysopogon montanus* (Trin.) | 38.50 | 154.00 | 1.75 | 7.00 | 0.50 | 28.89 |
| *Heteropogon contortus* (Linn) | 77.50 | 310.00 | 3.32 | 13.28 | 1.00 | 57.38 |
| *Capillipedium heugelli* (Hack.) | 85.00 | 340.00 | 3.28 | 13.12 | 1.00 | 59.70 |
| *Rumex hastatus* (Don.) | 11.00 | 44.00 | 18.94 | 75.76 | 1.00 | 82.84 |
| *Scutellaria grossa* (Wall.) | 96.00 | 384.00 | 5.91 | 23.64 | 1.00 | 71.19 |
| **Total** | **308.00** | **1232.00** | **33.20** | **132.80** | | |

**Table17:**
**Species composition of reclaimed limestone mined (13 years old) in Sal forest of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Trees** | | | | | | |
| *Acacia catechu* (Willd.) | 3.33 | 3.33 | 236.33 | 263.33 | 0.66 | 57.00 |
| *Dalbergia sissoo* (Roxb.) | 8.00 | 8.00 | 363.20 | 363.20 | 1.00 | 99.39 |
| *Leuceana leucocephala* (Lam deWit) | 4.67 | 4.67 | 109.97 | 109.97 | 0.33 | 40.78 |
| *Pyrus pashia* (Buch-Ham) | 0.33 | 0.33 | 2.31 | 2.31 | 0.33 | 11.66 |
| *Wendlandia exserta* (D C.) | 6.67 | 6.67 | 337.60 | 337.60 | 1.00 | 91.17 |
| **Total** | **23.00** | **23.00** | **1049.41** | **1049.41** | | |
| **Shrubs** | | | | | | |
| *Adhatoda vasica* (Nees.) | 1.00 | 4.00 | 5.78 | 23.12 | 0.14 | 5.13 |
| *Berberis lycium* (Royle.) | 1.14 | 4.56 | 3.94 | 15.76 | 0.14 | 5.06 |
| *Carissa spinarium* (Linn.) | 1.14 | 4.56 | 7.11 | 28.44 | 0.14 | 5.26 |
| *Dodonea viscosa* (L. Jacq.) | 2.71 | 10.84 | 65.63 | 262.52 | 0.28 | 13.88 |
| *Eupatorium reveesii* (Wall) | 301.43 | 1205.72 | 544.69 | 2178.76 | 1.00 | 136.83 |
| *Lantana camara* (Linn.) | 117.00 | 468.00 | 878.04 | 3512.16 | 0.86 | 110.19 |
| *Murraya koenigii* (Spreng.) | 0.57 | 2.28 | 3.73 | 14.92 | 0.28 | 9.49 |
| *Woodfordia fruiticosa* (L. Kurz) | 2.14 | 8.56 | 72.11 | 288.44 | 0.28 | 14.16 |
| **Total** | **427.13** | **1708.52** | **1581.03** | **6324.12** | | |
| **Grasses / Herbs** | | | | | | |
| *Arundinella nepalensis* (Trin.) | 13.67 | 1367.00 | 0.72 | 72.00 | 3.63 | 25.11 |
| *Digitaria stricta* (Roth.) | 12.67 | 1267.00 | 0.22 | 22.00 | 1.11 | 22.11 |
| *Saccharum spontaneum* (Linn.) | 26.00 | 2600.00 | 3.42 | 342.00 | 12.33 | 39.56 |
| *Dicliptera bupleuroides* (Nees.) | 38.83 | 3883.00 | 2.97 | 297.00 | 14.96 | 48.38 |
| *Fimbristylis rigidula* (Nees.) | 106.33 | 10633.00 | 8.29 | 829.00 | 41.76 | 112.20 |
| *Fragaria vesca* (linn.) | 6.33 | 633.00 | 0.40 | 40.00 | 2.01 | 15.01 |
| *Pilea scripta* (Wedd.) | 3.50 | 350.00 | 2.50 | 250.00 | 12.60 | 24.27 |
| *Viola serpens* (Wall.) | 3.50 | 350.00 | 1.33 | 133.00 | 6.70 | 13.36 |
| **Total** | **210.83** | **21083.00** | **19.85** | **1985.00** | | |

**Limestone mine in Sal forest**
**[Cement Corporation of India (CCI)]**

**Sal forest**
**(Near CCI limestone mine)**

**Ground vegetation of Sal forest**
**(Near CCI limestone mine)**

**Abandoned limestone mine in the Sal forest**
**(Six years old)**

***Wendlandia exserta*** **in reclaimed limestone mine in Sal forest**
**(Thirteen years old)**

***Acacia catechu*** **in reclaimed limestone mine in Sal forest**
**(Thirteen years old)**

**Plate 1**

Lime stone mined area of district Sirmaur in H.P exhibited two sub-types of dry mixed deciduous forest, one each on western and northern aspect (Plate 2). Both the sub-types were considered for vegetation analysis. Revegetation processes in mined area was studied in 5years, 10 years and 18 years old abandoned sites. These abandoned sites supported same type of vegetation as present in undisturbed forest sites prior to mining (Table 18).

The species composition of the undisturbed dry mixed deciduous forest on western aspect (Plate2) revealed 8 trees, 9 shrubs and 9 herbs. Total density of the trees recorded was 320.10 trees/ha. Highest tree density was recorded for *Phoenix acaulis* (170.00 trees/ha) followed by *Mallotus phillipinensis* (40.00 trees/ha) and *Bauhinia variegata* (30.00 trees/ha), whereas, *Bombax ceiba* had the lowest density (10.00 trees/ha). *Phoenix acaulis* had the highest basal area (1312.801 x $10^2$ $cm^2$/ha) amounting to 81.32 per cent of the total basal area (1614.223 x $10^2$ $cm^2$/ha) of trees. Basal area of *Phoenix acaulis* was followed by *Albizzia procera* and *Grewia optiva* with the respective basal areas as 62.433 x $10^2$ $cm^2$/ha and 55.407 x $10^2$ $cm^2$/ha. The lowest basal area among trees was recorded for *Bauhinia variegata* (20.701 x $10^2$ $cm^2$/ha). Comparing the IVI value of trees it was evident that *Phoenix acaulis* (150.24) was the dominant tree species. *Mallotus phillipinensis* (30.48) and *Bauhinia variegata* (26.46) were the associate tree species. All other species were rare as they exhibited very low IVI values (Table 18).

Total density of shrubs on the western aspect was 530.64 x $10^2$ stems/ha. Density of the *Hamiltonia suaveolens* was highest (164.00x $10^2$ stems/ha) followed by *Eupatorium reveesii* (121.32 x $10^2$ stems/ha). The density of other shrubs ranged from 5.32 x $10^2$ stems/ha to 74.68 x $10^2$ stems/ha with lowest density for *Debregeasia hypoleuca*. Comparing the basal area of shrubs, it was found that *Hamiltonia suaveolens* had the highest basal area amounting for 54.06 per cent (1519.96 x $10^2$ $cm^2$/ha) of the total basal area (2811.48 x $10^2$ $cm^2$/ha) of shrubs, whereas, lowest basal area was recorded for *Berberis ceratophylla* (28.52 x $10^2$ $cm^2$/ha). IVI values of the shrubs indicated that *Hamiltonia suaveolens* (99.97) was the dominant species on this site. *Eupatorium reveesii, Flacourtia indica, Lantanu camara* and *Indigofera pulchella* were the co-dominant species among shrubs with IVI as 38.00, 31.06, 35.83, and 32.13, respectively. All other shrubs exhibited low IVI values thus they were the rare species of the community (Table 18).

Appraisal of data on herbaceous vegetation in Table 18 revealed that grasses outnumbered forbs in density as well as basal area. Comparison of the density among herbs revealed that *Dicanthium annulatum* was having the highest density (28200.00x $10^2$ ind/ha) amounting to 23.86 per cent of the total density of herbs (118200.00x $10^2$ ind/ha). Density of *Dicanthium annulatum* was followed by *Ischaemum* spp. (23664.00 x $10^2$ ind/ha) and *Chrysopogon montanus* (23600.00 x $10^2$ ind/ha). Lowest density was recorded for *Dicliptera bupleuroides* (1000.00 x $10^2$ ind/ha). Basal area of the herbs recorded on the western aspect was 5936.00 x $10^2$ $cm^2$/ha. *Dicanthium annulatum* presented the highest basal area (2228.00 x $10^2$ $cm^2$/ha) among herbs. *Chrysopogon montanus* and *Chrysopogon gryllus* followed *Dicanthium annulatum* in basal area with their respective basal areas as 468.00 x $10^2$ $cm^2$/ha and 912.00 x $10^2$ $cm^2$/ha. The basal area of *Dicliptera bupleuroides* was least (20.00 x $10^2$ $cm^2$/ha). IVI values of herbs indicated that *Dicanthium annulatum* (80.15) was the dominant species. *Chrysopogon montanus* was the co-dominant species with IVI value of 63.44 and *Chrysopogon gryllus* (42.44) and *Ischaemum* spp. (38.22) were the associate species.

On the northern aspect in the dry mixed deciduous (Plate 2) forest 8 trees, 8 shrubs and 11 herbs were recorded (Table 19). Total density of the trees recorded at the site was 323.40 trees/ha. Highest density was recorded for *Acacia catechu* (1.30 x $10^2$ trees/ha) followed by *Phoenix acaulis* (0.50 x $10^2$ trees/ha) and *Mallotus phillipinensis* (0.40 x $10^2$ trees/ha); whereas lowest density was recorded for *Aegle marmelos, Celtis australis* and *Grewia optiva* (0.167 x $10^2$ trees/ha). The highest basal area was exhibited by *Phoenix acaulis* accounting to 45.54 per cent (303.995 x $10^2$ $cm^2$/ha) of the total basal area (667.47 x $10^2$ $cm^2$/ha) of trees. *Grewia optiva,* *Aegle marmelos* and *Acacia catechu* followed *Phoenix acaulis* in basal area with their respective basal areas as 69.513 x $10^2$ $cm^2$/ha, 66.235 x $10^2$ $cm^2$/ha and 64.818 x $10^2$ $cm^2$/ha. *Bauhinia variegata* accounted for the lowest basal area among trees (24.140 x $10^2$ $cm^2$/ha). IVI values of the trees indicated that *Phoenix acaulis* and *Acacia catechu* were the dominant species with their respective IVI values as 75.28 and 64.20. *Rhus parviflora*, *Mallotus phillipinensis* and *Aegle marmelos* were the co-dominant species with their IVI values as 34.04, 31.65 and 29.38, respectively. *Celtis australis* and *Bauhinia variegata* were the associate species (Table 19).

Total density of the shrubs recorded was 486.68 x $10^2$ stems/ha. Density of *Hamiltonia suaveolens* was highest (166.68 x $10^2$ stems/ha) followed by *Lantana camara* (144.00 x $10^2$ stems/ha), whereas, lowest density was recorded for *Murraya koenigii* (6.68 x $10^2$ stems/ha). Basal area of shrubs revealed that *Hamiltonia suaveolens* had the highest basal area (1535.20 x $10^2$ $cm^2$/ha) and accounted for 55.15 per cent of the total basal area of shrubs (2783.60 x $10^2$ $cm^2$/ha) followed by *Flacourtia indica* (344.20 x $10^2$ $cm^2$/ha) and *Coriaria nepalensis* (258.76 x $10^2$ $cm^2$/ha). Lowest basal area was recorded for *Berberis ceratophylla* (33.32 x $10^2$ $cm^2$/ha). IVI values revealed that *Hamiltonia suaveolens* (106.07) was the dominant shrub. *Lantana camara* and *Flacourtia indica* were the co-dominant shrubs with IVI values of 54.36 and 39.16, respectively. *Coriaria nepalensis* (28.08) was the associate species (Table 19).

Among the herbaceous vegetation, grasses had higher density and basal area as compared to forbs. The total density of the herbs recorded on this site was 108668.00 x $10^2$ ind/ha. *Chrysopogon montanus* had the highest density (26667.00 x $10^2$ ind/ha) followed by *Ischaemum* spp (23733.00 x $10^2$ ind/ha) and *Chrysopogon gryllus* (19733.00 x $10^2$ ind/ha). Highest basal area recorded for *Chrysopogon montanus* accounted for 26.05 per cent (1533.00 x $10^2$ $cm^2$/ha) of the total basal area of herbs (5885.00 x $10^2$ $cm^2$/ha). *Siegesbeckia orientalis* was recorded to have the lowest density (267.00 x $10^2$ ind/ha) and lowest basal area (51.00 x$10^2$ $cm^2$/ha) among herbs. Comparison of the IVI values indicated that Chrysopogon *montanus* (66.38) was the dominant species among herbs. *Chrysopogon gryllus* and *Ischaemum* spp. were the co-dominant species with IVI values as 45.88 and 45.93, respectively. *Themeda anathera* (33.97) and *Oplismenus compositus* (28.82) were the associate species in this community (Table 19).

The abandoned limestone mine (5 years old) adjacent to dry mixed deciduous forest (Plate 2) supported 7 shrubs and 2 herbs (Table 20). Tree /saplings were absent in this site. Density of shrubs (1914.00 x $10^2$ stems/ha) on this site showed that *Eupatorium reveesii* had the highest density (884.00 x $10^2$ stems/ha) followed by *Caryopteris spp.* (632.00 x $10^2$ stems/ha) and Roylea *elegans* (340.00 x $10^2$ stems/ha). Total basal area of shrubs was 2795.20 x $10^2$cm$^2$/ha. Decreasing order of basal area was recorded for *Eupatorium reveesii* (1647.80 x $10^2$ cm$^2$/ha), *Roylea elegans* (668.60 x $10^2$ cm$^2$/ha) and *Debregeasia hypoleuca* (203.28 x $10^2$ cm$^2$/ha). Lowest density (6.00 x $10^2$ ind/ha) and lowest basal area (1.48 x $10^2$ cm$^2$/ha) among shrubs was exhibited by *Aerua scandens* (Table 20). Comparing the IVI values of shrubs it was evident that *Eupatorium reveesii* (127.35) was the dominant species. *Caryopteris spp.* (46.54), *Roylea elegans* (52.80) were the co-dominant species. *Mimosa rubicaulis* was the associate species with IVI value as 28.86.

Only two herbaceous species were recorded in this site with total density as 460.00 x $10^2$ ind/ha and basal area as 18.28 x $10^2$ cm$^2$/ha. The sedge *Cyperus rotundus* represented 68.26 per cent of the total population and accounted for 49.45 per cent of the total basal area. Thus, it was the dominant species on this site (Table 20).

Abandoned limestone mine (10 years old) in dry mixed deciduous forest (Plate 2) comprised of 5 shrubs and 5 herbs. Trees were also absent here. Density of shrubs (3344.20 x $10^2$ind/ha) on this site showed that *Eupatorium reveesii* has the highest density (3110.00 x $10^2$ ind/ha) followed by *Aechmenthera tomentosa* (154.20 x $10^2$ in/ha). Comparing the basal area of shrubs clearly indicated that *Eupatorium reveesii* has the highest basal area (5797.04 x $10^2$ cm$^2$/ha) accounting to 89.92 per cent of the total basal area of shrubs (6446.72 x $10^2$ cm$^2$/ha). Thus, it was a dominant species with IVI value of 207.91 (Table 21).

Forbs outnumbered the grasses in both density as well as basal area. Grasses accounted for mere 10.64 per cent (206.00 x $10^2$ ind/ha) of the total density (1936.00 x $10^2$ ind/ha) and 0.41per cent (8.68x $10^2$ cm$^2$/ha) of the total basal area (2138.76 x $10^2$ cm$^2$/ha) of herbs. Highest density and basal area among herbs was exhibited by *Rumex hastatus* with respective values as 1080.00 x $10^2$ ind/ha and 2096.28 x $10^2$ cm$^2$/ha, whereas, *Arundinella nepalensis* recorded lowest density and basal area (46.00 x $10^2$ ind/ha; 1.08 x $10^2$ cm$^2$/ha). IVI values of herbs indicated that *Rumex hastatus* (178.80) was the dominant species with *Cyperus rotundus* (50.86) as co-dominant species. *Scutellaria grossa* (34.29) was the associate species in this community (Table 21).

The species composition of 18 years old abandoned limestone mine in the dry mixed deciduous forest (Plate 2) revealed the presence of 2 trees, 5 shrubs and 5 herbs. 1000 trees/ha with basal area of 67.80 x $10^2$ cm$^2$/ha were recorded. Highest density was exhibited by *Trema politoria* (6.00 x $10^2$ trees/ha) but highest basal area was recorded for *Acacia catechu* (49.44 x $10^2$ cm$^2$/ha). *Acacia catechu* dominated the site with IVI value of 162.92 (Table 22).

Among shrubs, highest density (4704.00 x $10^2$ stems/ha) was recorded for *Eupatorium reveesii*, accounting to 96.62 per cent of the total density of shrubs (4868.68 x $10^2$ stems/ha). Like wise, the basal area of *Eupatorium reveesii* accounted for 88.90 per cent (8768.24 x $10^2$ cm$^2$/ha) of the total basal area of shrubs (9863.00 x $10^2$ cm$^2$/ha). Thus, it was a dominant shrub species having IVI value of 215.74.

Data on the herbaceous vegetation revealed that forbs outnumbered grasses in population as well as basal area. 82.75 per cent of the total density of herbs (2284.00 x $10^2$ ind/ha) was represented by *Rumex hastatus* (1890.00 x $10^2$ind/ha). Likewise, this species accounted for 99.24 per cent (3668.52 x $10^2$ cm$^2$/ha) of the total basal area of herbs (3696.56 x $10^2$ $cm^2$/ha). Thus, it was the dominant species of this community with IVI value of 215.31(Table 22).

Under Quercus forest three sites representing (a) Undistributed Quercus forest (b) 8 years old abandoned mine site and (c) Reclaimed mine site (12 years old) were studied for vegetation analysis that revealed the following:

Species composition of the undisturbed Quercus forest (Plate 3) comprised of 2 trees, 9 shrubs and 10 herbs. 1000 trees/ha were recorded in this forest with a total basal area of 2149.33 x $10^2$ $cm^2$/ha. *Quercus leucotricophora* accounted for 90.00 per cent (9.00 x $10^2$ trees/ha) of the total density of the trees. Like wise, this species represented 99.45 per cent (2137.39 x $10^2$ $cm^2$/ha) of the total basal area of trees. Thus, it was a domination tree species on the site with *Pyrus pashia* as an associate species (Table 23).

Total density of the shrubs recorded on this site was 179.00 x $10^2$ stems/ha. Comparing the density of all shrubs it was evident that *Myrsine africanca* maintained highest density (31.00 x $10^2$ stems/ha) followed by *Flemingia fruiticulosa* (26.00 x $10^2$ stems/ha) and *Leptodermis lanceolata* (24.00 x $10^2$ stems/ha), whereas, lowest density among shrubs was recorded for *Rosa brunonii* (3.25 x $10^2$ stems/ha). Highest basal area was recorded for *Rhamanus virgatus*, which accounted for 26.77 per cent (179.92 x $10^2$ $cm^2$/ha) of the total basal area of shrubs (671.92 x $10^2$ $cm^2$/ha) closely followed by *Leptodermis lanceolata* (164.84 x $10^2$ $cm^2$/ha). Lowest basal area was recorded for *Flemingia fruiticulosa* (7.92 x $10^2$ $cm^2$/ha). IVI values of shrubs indicated that *Leptodermis lanceolata* and *Rhamanus virgatus* were the dominant species in the community with respective IVI values as 49.70 and 48.05. *Myrsine africanca* (41.89) was co-dominant species with them. *Berberis lycium, Flemingia fruiticulosa, Jasminum humile* and *Rabdosia rugosa* were the associate species (Table 23).

Herbaceous vegetation revealed that grasses had higher density and basal area than forbs. *Dicanthium annulatum* recorded the highest density (27800.00 x $10^2$ ind/ha),

**Table18:**

**Species composition of dry mixed deciduous forest (western aspect) in the limestone mine area of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq. | IVI |
|---|---|---|---|---|---|---|
| | | | **Trees** | | | |
| *Albizzia procera* (Roxb.) | 1.67 | 0.167 | 624.33 | 62.433 | 0.66 | 19.59 |
| *Bauhinia variegata* (Linn.) | 3.00 | 0.300 | 207.01 | 20.701 | 1.00 | 26.46 |
| *Bombax ceiba* (Linn.) | 1.00 | 0.100 | 393.88 | 39.388 | 0.66 | 16.08 |
| *Celtis australis* (Linn.) | 1.67 | 0.167 | 424.11 | 42.411 | 0.66 | 18.36 |
| *Ficus palmata* (Forsk.) | 2.00 | 0.200 | 459.27 | 45.927 | 0.50 | 19.61 |
| *Grewia optiva* (Drumm.ex.Burr.) | 1.67 | 0.167 | 554.07 | 55.407 | 0.66 | 19.18 |
| *Mallotus phillipinensis* (Muell.Arg) | 4.00 | 0.400 | 351.55 | 35.155 | 1.00 | 30.48 |
| *Phoenix acaulis* (Roxb.) | 17.00 | 1.7 0 | 13128.01 | 1312.801 | 1.00 | 150.24 |
| **Total** | **32.01** | **3.201** | **16142.23** | **1614.223** | | |
| | | | **Shrubs** | | | |
| *Berberis ceratophylla* (G.Don) | 6.33 | 25.32 | 7.13 | 28.52 | 0.66 | 15.79 |
| *Berberis lycium* (Royle.) | 9.00 | 36.00 | 13.46 | 53.84 | 0.66 | 18.69 |
| *Debregeasia hypoleuca* (Wedd.) | 1.33 | 5.32 | 30.13 | 120.52 | 0.33 | 10.29 |
| *Eupatoium reveesii* (Wall.) | 30.33 | 121.32 | 36.07 | 144.28 | 0.66 | 38.00 |
| *Flacourtia indica* (Roxb.) | 9.67 | 38.68 | 61.63 | 246.52 | 1.00 | 31.06 |
| *Hamiltonia suaveolens* (Roxb.) | 41.00 | 164.00 | 379.99 | 1519.96 | 1.00 | 99.97 |
| *Indigofera pulchella* (Roxb.) | 13.33 | 53.32 | 84.88 | 339.52 | 0.66 | 32.13 |
| *Lantana camara* (Linn.) | 18.67 | 74.68 | 47.55 | 190.20 | 1.00 | 35.83 |
| *Murraya koenigii* (Spreng.) | 3.00 | 12.00 | 42.03 | 168.12 | 0.66 | 18.24 |
| **Total** | **132.66** | **530.64** | **702.87** | **2811.48** | | |
| | | | **Grasses/Herbs** | | | |
| *Arundinella nepalensis* (Trin.) | 90.68 | 9068 | 4.08 | 408.00 | 0.50 | 23.93 |
| *Chrysopogon gryllus* (Linn.) | 170.00 | 17000 | 9.12 | 912.00 | 0.66 | 42.24 |
| *Chrysopogon montanus* (Trin.) | 236.00 | 23600 | 14.68 | 1468.00 | 1.00 | 63.44 |
| *Dicathium annulatum* (Forssk.) | 282.00 | 28200 | 22.28 | 2228.00 | 1.00 | 80.15 |
| *Imperta cylindrica* (Linn.) | 65.32 | 6532 | 2.32 | 232.00 | 0.33 | 15.67 |
| *Ischaemum spp.* | 236.64 | 23664 | 5.24 | 524.00 | 0.50 | 38.22 |
| *Cassia tora* (Linn.) | 12.68 | 1268 | 0.36 | 36.00 | 0.33 | 7.93 |
| *Dicliptera bupleuroides* (Nees.) | 10.00 | 1000 | 0.20 | 20.00 | 0.50 | 7.44 |
| *Micromeria biflora* (Benth.) | 78.68 | 7868 | 1.08 | 108.00 | 0.66 | 20.98 |
| **Total** | **1182** | **118200** | **59.36** | **5936.00** | | |

**Table19:**

**Species composition of dry mixed deciduous forest (northern aspect) in the limestone mine area of district Sirmaur (H.P.)**

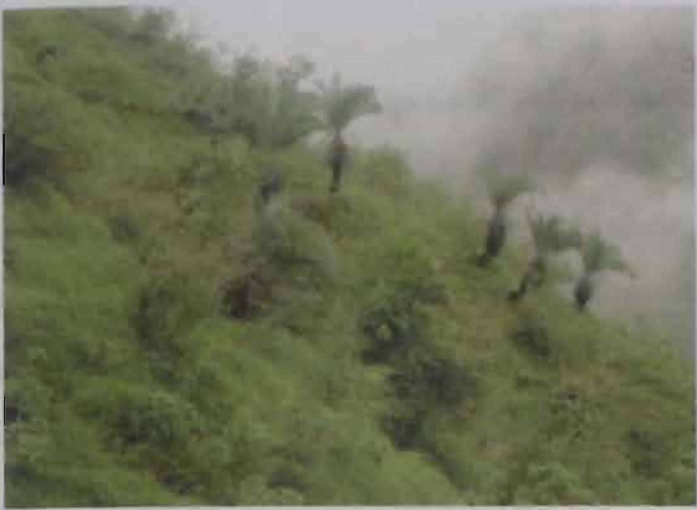
| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| | | | **Trees** | | | |
| *Acacia catechu* (Willd.) | 13.00 | 1.300 | 648.18 | 64.818 | 1.00 | 64.20 |
| *Aegle marmelos* (Correa) | 1.67 | 0.167 | 662.35 | 66.235 | 1.00 | 29.38 |
| *Bauhinia variegata* (Linn.) | 2.00 | 0.200 | 241.40 | 24.140 | 0.66 | 19.33 |
| *Celtis australis* (Linn.) | 1.67 | 0.167 | 423.90 | 42.390 | 0.66 | 21.03 |
| *Grewia optiva* (Drumm.ex.Burr.) | 1.67 | 0.167 | 695.13 | 69.513 | 0.66 | 25.09 |
| *Mallotus phillipinensis* (Muell.Arg.) | 4.00 | 0.4 00 | 333.12 | 33.312 | 1.00 | 31.65 |
| *Phoenix acaulis* (Roxb.) | 5.00 | 0.500 | 3039.95 | 303.995 | 1.00 | 75.28 |
| *Rhus parviflora* (Roxb.) | 3.33 | 0.333 | 630.67 | 63.067 | 1.00 | 34.04 |
| **Total** | **32.34** | **3.234** | **6674.70** | **667.470** | | |
| | | | **Shrubs** | | | |
| *Berberis ceratophylla* (G.Don) | 8.33 | 33.32 | 8.33 | 33.32 | 0.66 | 19.15 |
| *Berberis lycium* (Royle.) | 9.67 | 38.68 | 12.12 | 48.48 | 0.66 | 20.79 |
| *Coriaria nepalensis* (Wall.) | 9.33 | 37.32 | 64.69 | 258.76 | 0.66 | 28.08 |
| *Debregeasia hypoleuca* (Wedd.) | 2.67 | 10.68 | 60.26 | 241.04 | 0.66 | 21.97 |
| *Flacourtia indica* (Roxb.) | 12.33 | 49.32 | 86.05 | 344.20 | 1.00 | 39.16 |
| *Hamiltonia suaveolens* (Roxb.) | 41.67 | 166.68 | 383.80 | 1535.20 | 1.00 | 106.07 |
| *Lantana camara* (Linn.) | 36.00 | 144.00 | 56.42 | 225.68 | 1.00 | 54.36 |
| *Murraya koenigii* (Spreng.) | 1.67 | 6.68 | 24.23 | 96.92 | 0.33 | 10.42 |
| **Total** | **121.67** | **486.68** | **695.90** | **2783.60** | | |
| | | | **Grasses/ Herbs** | | | |
| *Arundinella nepalensis*(Trin.) | 32.67 | 3267.00 | 1.35 | 135.00 | 0.50 | 13.20 |
| *Chrysopogon gryllus* (Linn.) | 197.33 | 19733.00 | 10.12 | 1012.00 | 0.66 | 45.88 |
| *Chrysopogon montanus* (Trin.) | 266.67 | 26667.00 | 15.33 | 1533.00 | 1.00 | 66.38 |
| *Ischaemum spp.* | 237.33 | 23733.00 | 7.99 | 799.00 | 0.66 | 45.93 |
| *Oplismenus compositus* (Linn.) | 88.67 | 8867.00 | 7.51 | 751.00 | 0.50 | 28.82 |
| *Themeda anathera* (Nees.) | 98.00 | 9800.00 | 6.95 | 695.00 | 0.83 | 33.97 |
| *Bidens pillosa* (Linn.) | 48.00 | 4800.00 | 5.23 | 523.00 | 0.50 | 21.22 |
| *Cyperus rotundus* (Linn.) | 10.00 | 1000.00 | 0.54 | 54.00 | 0.50 | 9.75 |
| *Dicliptera bupleuroides* (Nees.) | 42.67 | 4267.00 | 2.12 | 212.00 | 0.50 | 15.42 |
| *Micromeria biflora* (Benth.) | 62.67 | 6267.00 | 1.20 | 120.00 | 0.50 | 15.71 |
| *Siegesbeckia orientalis* (Linn.) | 2.67 | 267.00 | 0.51 | 51.00 | 0.16 | 3.72 |
| **Total** | **1086.68** | **108668.00** | **58.85** | **5885.00** | | |

**Table 21:**
**Species composition of abandoned limestone mine (10 years old) in dry mixed deciduous forest of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Shrubs** | | | | | | |
| *Aechmenthera tomentosa* (Nees.) | 38.55 | 154.20 | 69.76 | 279.04 | 1.00 | 33.94 |
| *Boehmeria platyphylla* (Don.) | 9.50 | 38.00 | 8.11 | 32.44 | 1.00 | 26.64 |
| *Debregeasia hypoleuca* (Wedd.) | 7.00 | 28.00 | 75.99 | 303.96 | 0.50 | 18.06 |
| *Eupatorium reveesii* (Wall.) | 777.50 | 3110.00 | 1449.26 | 5797.04 | 1.00 | 207.91 |
| *Rabdosia rugosa* (Wallich ex.Benth.) | 3.50 | 14.00 | 8.56 | 34.24 | 0.50 | 13.45 |
| **Total** | **836.05** | **3344.20** | **1161.68** | **6446.72** | | |
| **Grasses/ Herbs** | | | | | | |
| *Arundinella nepalensis* (Trin.) | 11.50 | 46.00 | 0.27 | 1.08 | 0.50 | 14.94 |
| *Chrysopogon gryllus* (Linn.) | 40.00 | 160.00 | 1.90 | 7.60 | 0.50 | 21.11 |
| *Cyperus rotundus* (Linn.) | 120.00 | 480.00 | 5.70 | 22.80 | 1.00 | 50.86 |
| *Scutellaria grossa* (Wall.) | 42.50 | 170.00 | 2.75 | 11.00 | 1.00 | 34.29 |
| *Rumex hastatus* (Don) | 270.00 | 1080.00 | 524.07 | 2096.28 | 1.00 | 178.80 |
| **Total** | **484.00** | **1936.00** | **534.69** | **2138.76** | | |

**Table 22:**
**Species composition of abandoned limestone mine (18 years old) in dry mixed deciduous forest of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Trees** | | | | | | |
| *Acacia catechu* (Willd.) | 1.00 | 4.00 | 12.36 | 49.44 | 0.50 | 162.92 |
| *Trema politoria* (Planch.) | 1.50 | 6.00 | 4.59 | 18.36 | 0.50 | 137.08 |
| **Total** | **2.50** | **10.00** | **16.95** | **67.80** | | |
| **Shrubs** | | | | | | |
| *Eupatorium reveesii* (Wall.) | 1176.00 | 4704.00 | 2192.06 | 8768.24 | 1.00 | 215.74 |
| *Lantana camara* (Linn.) | 21.50 | 86.00 | 109.44 | 437.76 | 1.00 | 34.85 |
| *Leptodermis lanceolata* (Wall.) | 2.00 | 8.00 | 4.01 | 16.04 | 0.50 | 14.62 |
| *Lespedza eriocarpa* (DC.) | 11.67 | 46.68 | 105.94 | 423.76 | 0.50 | 19.62 |
| *Woodfordia fruiticosa* (L. Kurz) | 6.00 | 24.00 | 9.30 | 37.20 | 0.50 | 15.17 |
| **Total** | **1217.17** | **4868.68** | **2420.75** | **9863.00** | | |
| **Grasses/Herbs** | | | | | | |
| *Heteropopgon contortus* (Linn.) | 45.00 | 180.00 | 1.44 | 5.76 | 0.50 | 24.71 |
| *Viteveria zizanoides* (Linn.) | 11.00 | 44.00 | 2.24 | 8.96 | 0.50 | 18.84 |
| *Cyperus rotundus* (Linn.) | 17.50 | 70.00 | 0.31 | 1.24 | 0.50 | 19.77 |
| *Rumex hastatus* (Don) | 472.50 | 1890.00 | 917.13 | 3668.52 | 1.00 | 215.31 |
| *Tridax procumbens* (Linn.) | 25.00 | 100.00 | 3.02 | 12.08 | 0.50 | 21.37 |
| **Total** | **571.00** | **2284.00** | **924.14** | **3696.56** | | |



**Dry mixed deciduous forest (Western aspect)**

**Dry mixed deciduous forest (Northern aspect)**

**Abandoned limestone mine in dry mixed deciduous forest (Five years old)**

**Abandoned limestone mine in dry mixed deciduous forest (Ten years old)**

**Abandoned limestone mine in dry mixed deciduous forest (Eighteen years old)**

**Plate 2**

closely followed by *Paspalum paspaloides* which accounted for 22.28 per cent ($23868.00 \times 10^2$ ind/ha), of the total density of herbs ($107136.00 \times 10^2$ ind/ha). Among forbs, *Micromeria biflora* exhibited highest density ($5732.00 \times 10^2$ ind/ha). Lowest density among herbs was recorded for *Roscoea alpina* ($264.00 \times 10^2$ ind/ha). Total basal area recorded for herbs was $5652.00 \times 10^2$ $cm^2$/ha. Comparing the basal area of constituent herbs it was evident that *Dicanthium annulatum* achieved the highest basal area ($1440.00 \times 10^2$ $cm^2$/ha) closely followed by *Paspalum paspaloides* ($1416.00 \times 10^2$ $cm^2$/ha). Lowest basal area was recorded for *Roscoea alpina* ($76.00 \times 10^2$ $cm^2$/ha). *Dicanthium annulatum* and *Paspalum paspaloides* were the dominant species among herbs with their IVI values as 67.20 and 63.12, respectively. *Panicum maximum* and *Eragrostis nigra* were the co-dominant species with IVI values as 48.46 and 47.18 respectively. All other species of herbs revealed comparatively low IVI and thus were rare species in the community (Table 23).

The abandoned limestone site in Quercus forest (Plate 3) revealed that the trees were absent in this site. However, 2 shrubs and 6 herbs were growing on this site. *Eupatorium reveesii* accounted for 99.27 ($4360.00 \times 10^2$ stems/ha) of the total density of shrubs ($4392.00 \times 10^2$ stems/ha). Likewise, basal area of *Eupatorium reveesii was* $11308.72 \times 10^2$ $cm^2$/ha which accounted for 96.35 per cent of total basal area of shrubs ($11736.92 \times 10^2$ $cm^2$/ha). *Dabregeasia hypoleuca* was found to be an associate species (Table 24).

Only one grass (*Arundinella nepalensis*) was recorded on this site. Forbs exhibited higher population and maintained higher basal area as compared to the grass. Total density of the herbaceous vegetation on this site was $1774.68 \times 10^2$ ind/ha. *Rumex hastatus* exhibited the highest density ($573.32 \times 10^2$ ind/ha) followed by *Fimbristylis rigidula* ($532.00 \times 10^2$ ind/ha) and *Cyperus rotundus* ($394.68 \times 10^2$ ind/ha). Lowest density was recorded for *Anaphalis* spp. ($33.32 \times 10^2$ ind/ha). Forbs accounted for 99.63 per cent ($2331.12 \times 10^2$ $cm^2$/ha) of the total basal area of herbs ($2339.80 \times 10^2$ $cm^2$/ha). Highest basal area was recorded for *Rumex hastatus* ($2243.48 \times 10^2$ $cm^2$/ha), whereas, the lowest basal area ($8.68 \times 10^2$ $cm^2$/ha) was exhibited by *Arundinella nepalensis* (Table 24). Comparison of the IVI values indicated that *Rumex hastatus* was the dominant species with IVI value of 146.90. *Fimbristylis rigidula* and *Cyperus rotundus* followed it with IVI values as 50.59 and 41.62, respectively and thus, were the associate species (Table 24).

Three trees, six shrubs and seven herbs were growing in reclaimed mined area (Plate 3). *Robinia pseudocasia* accounted for 84.85 per cent (14.00 x $10^2$ trees/ha) of the total density of trees (16.50 x $10^2$ trees/ha). Likewise, 73.25 per cent (558.90 x $10^2$ $cm^2$/ha) of the total basal area (763.00 x $10^2$ $cm^2$/ha) was represented by this species. Thus, it was a dominant tree species with IVI value of 208.10 with *Bauhinia variegata* and *Populus deltoides* as associate species (Table 25).

Among shrubs, *Eupatorium reveesii* exhibited highest density (2333.32 x $10^2$ stems/ha) accounting to 94.95 per cent of the total density (2457.32 x $10^2$ stems/ha). Like wise, 87.97 per cent (5669.72 x $10^2$ $cm^2$/ha) of the total basal area (6445.04 x $10^2$ $cm^2$/ha) of shrubs was represented by this species. IVI value of the shrubs indicated that *Eupatorium reveesii* was the dominant shrub with IVI value of 207.91 (Table 25).

Data on the herbaceous vegetation on this site revealed that the population and basal area of forbs was comparatively much higher than the grasses. Only two grass species, *Digitaria stricta* and *Panicum maximum* were recorded on this site. Highest density was recorded for *Aster mollusculus,* which accounted for 47.79 per cent (13000.00 x 10 ind/ha) of the total density (27200.00 x $10^2$ ind/ha) of herbs whereas, lowest density was exhibited by *Geranium nepalensis* (625.00 x $10^2$ ind/ha). Basal area of herbaceous vegetation revealed that forbs accounted for 95.51 per cent (1466 x $10^2$ $cm^2$/ha) of total basal area of herbs (1535.00 x $10^2$ $cm^2$/ha). Highest basal area was recorded for *Aster mollusculus* (827.00 x $10^2$ $cm^2$/ha) whereas, *Panicum maximum* exhibited the least basal area among herbs (33.00 x $10^2$ $cm^2$/ha). Comparing the IVI values of herbs it was evident that *Aster mollusculus* (120.72) was the dominant species. *Dicliptera bupleuroides* (61.03) and *Malvestrum coromandelianum* (46.96) were the co-dominant species (Table25).

**Table23:**
**Species composition of Quercus forest in limestone mine area of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Trees** | | | | | | |
| *Pyrus pashia* (Buch.-Ham.) | 1.00 | 1.00 | 11.94 | 11.94 | 0.66 | 50.55 |
| *Quercus leucotricophora* (A. Camus ex. Bahadur) | 9.00 | 9 .00 | 2137.39 | 2137.39 | 1.00 | 249.45 |
| **Total** | **10.00** | **10.00** | **2149.33** | **2149.33** | | |
| **Shrubs** | | | | | | |
| *Berberis lycium* (Royle.) | 3.75 | 15.00 | 20.20 | 80.80 | 050 | 32.17 |
| *Eupatorium reveesii* (Wall.) | 4.25 | 17.00 | 09.27 | 37.08 | 0.25 | 20.91 |
| *Flemingia fruiticulosa* (Wall.) | 6.50 | 26.00 | 1.98 | 7.92 | 0.50 | 27.46 |
| *Leptodermis lanceolata* (Wall.) | 6.00 | 24.00 | 41.21 | 164.84 | 0.50 | 49.70 |
| *Jasminum humile* (Linn.) | 3.75 | 15.00 | 10.87 | 43.48 | 0.50 | 26.62 |
| *Myrsine africana* (Linn.) | 7.75 | 31.00 | 21.52 | 86.08 | 0.50 | 41.89 |
| *Rabdosia rugosa* (Wallich. ex.Benth.) | 5.25 | 21.00 | 10.28 | 41.12 | 0.50 | 29.62 |
| *Rhamanus virgatus* (Roxb.) | 4.25 | 17.00 | 44.98 | 179.92 | 0.50 | 48.05 |
| *Rosa brunonii* (Lindley) | 3.25 | 13.00 | 7.67 | 30.68 | 0.50 | 23.58 |
| **Total** | **44.75** | **179.00** | **167.98** | **671.92** | | |
| **Grasses/Herbs** | | | | | | |
| *Arundinella nepalensis* (Trin.) | 32.00 | 3200.00 | 1.48 | 148.00 | 0.33 | 10.86 |
| *Chrysopogon montanus* (Trin.) | 48.00 | 4800.00 | 1.76 | 176.00 | 0.33 | 12.88 |
| *Dicanthium annulatum* (Forssk.) | 278.00 | 27800.00 | 14.40 | 1440.00 | 1.00 | 67.20 |
| *Eragrostis nigra* (Nees.) | 200.00 | 20000.00 | 8.68 | 868.00 | 0.83 | 47.18 |
| *Panicum maximum* (Jacq.) | 201.36 | 20136.00 | 7.84 | 784.00 | 1.00 | 48.46 |
| *Paspalum paspoloides* (Scribn.) | 238.68 | 23868.00 | 14.16 | 1416.00 | 1.00 | 63.12 |
| *Conyza spp.* | 6.68 | 668.00 | 1.68 | 168.00 | 0.50 | 11.48 |
| *Micromeria biflora* (Benth.) | 57.32 | 5732.00 | 2.40 | 240.00 | 0.33 | 17.48 |
| *Roscoea alpina* ( Royle.) | 2.64 | 264.00 | 0.76 | 76.00 | 0.16 | 4.23 |
| *Salvia lannata* (Roxb.) | 6.68 | 668.00 | 3.36 | 336.00 | 0.66 | 17.11 |
| **Total** | **1071.36** | **107136.00** | **56.52** | **5652.00** | | |

**Table 24:**
**Species composition of abandoned limestone mine (8 years old) in Quercus forest of district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Shrubs** | | | | | | |
| *Debregeasia hypoleuca* (Wedd.) | 8.00 | 32.00 | 107.05 | 428.20 | 0.66 | 44.38 |
| *Eupatorium reveesii* (Wall.) | 1090.00 | 4360.00 | 2827.18 | 11308.72 | 1.00 | 255.62 |
| Total | **1098.00** | **4392.00** | **2934.23** | **11736.92** | | |
| **Grasses / Herbs** | | | | | | |
| *Arundinella nepalensis* (Trin.) | 40.67 | 162.68 | 2.17 | 8.68 | 0.66 | 22.04 |
| *Cyperus rotundus* (Linn.) | 98.67 | 394.68 | 3.67 | 14.68 | 1.00 | 41.62 |
| *Fimbristylis rigidula* (Nees.) | 133.00 | 532.00 | 10.90 | 43.60 | 1.00 | 50.59 |
| *Anaphalis spp.* | 8.33 | 33.32 | 2.38 | 9.52 | 1.00 | 21.04 |
| *Bidens pillosa* (Linn.) | 19.67 | 78.68 | 5.13 | 20.52 | 0.66 | 17.81 |
| *Rumex hastatus* (Don) | 143.33 | 573.32 | 560.87 | 2243.48 | 1.00 | 146.90 |
| **Total** | **443.67** | **1774.68** | **584.95** | **2339.80** | 1.00 | |

**Table25:**
**Species composition of reclaimed limestone mine (12 years old) in Quercus forestof district Sirmaur (H.P.)**

| Species | Density (no./quad) | Density (no./ha) x $10^2$ | Basal area ($cm^2$/quad) | Basal area ($cm^2$/ha) x $10^2$ | Freq | IVI |
|---|---|---|---|---|---|---|
| **Trees** | | | | | | |
| *Bauhinia variegata* (Linn.) | 1.50 | 1.50 | 18.27 | 18.27 | 0.50 | 36.49 |
| *Populus deltoides* (Bartr. ex. Marsh.) | 1.00 | 1.00 | 185.83 | 185.83 | 0.50 | 55.41 |
| *Robinia pseudocasia* (Linn.) | 14.00 | 14.00 | 558.90 | 558.90 | 1.00 | 208.10 |
| **Total** | **16.50** | **16.50** | **763.00** | **763.00** | | |
| **Shrubs** | | | | | | |
| *Berberis ceratophylla* (G.Don.) | 3.00 | 12.00 | 10.22 | 40.88 | 0.66 | 17.80 |
| *Berberis lycium* (Royle.) | 3.67 | 14.68 | 14.62 | 58.48 | 0.66 | 18.18 |
| *Debregeasia hypoleuca* (Hochst. Wedd.) | 6.67 | 26.68 | 117.16 | 468.64 | 0.66 | 25.01 |
| *Eupatorium reveesii* (Wall.) | 583.33 | 2333.32 | 1417.43 | 5669.72 | 1.00 | 207.91 |
| *Rabdosia rugosa* (Wallich. ex.Benth.) | 16.33 | 65.32 | 37.21 | 148.84 | 0.66 | 21.64 |
| *Rubus ellipticus* (Smith.) | 1.33 | 5.32 | 14.62 | 58.48 | 0.33 | 9.46 |
| **Total** | **614.33** | **2457.32** | **1611.26** | **6445.04** | | |
| **Grasses / Herbs** | | | | | | |
| *Digitaria stricta* (Roth.) | 8.50 | 850.00 | 0.36 | 36.00 | 0.50 | 14.98 |
| *Panicum maximum* (Jacq.) | 7.75 | 775.00 | 0.33 | 33.00 | 0.50 | 14.52 |
| *Aster mollusculus* (Wall.) | 130.00 | 13000.00 | 8.27 | 827.00 | 1.00 | 120.72 |
| *Bidens pillosa* (Linn.) | 14.25 | 1425.00 | 1.23 | 123.00 | 0.50 | 22.78 |
| *Dicliptera bupleuroides* ( Nees.) | 61.75 | 6175.00 | 2.96 | 296.00 | 1.00 | 61.03 |
| *Geranium nepalensis* (Sweet) | 6.25 | 625.00 | 0.37 | 37.00 | 0.75 | 19.01 |
| *Malvastrum coromandelianum* (Garcke.) | 43.50 | 4350.00 | 1.83 | 183.00 | 1.00 | 46.96 |
| **Total** | **272.00** | **27200.00** | **15.35** | **1535.00** | | |

**Quercus forest**

**Abandoned limestone mine in Quercus forest**
**(Eight years old)**

**Reclaimed limestone mine in Quercus forest**
**(Twelve years old)**

**Plate 3**

## 4.2 Physico–chemical characteristics of mined and mine free areas

Soil separates of reclaimed site (13 years old) in Moist Shiwalik Sal forest zone showed that proportion of sand increased from 47.37 per cent to 62.45 per cent in 0-20 cm soil depth, but silt and clay decreased from 35.50 per cent to 26.06 per cent and 17.13 per cent, respectively (Table 26). In the lower depth of soil (20 – 40 cm ) similar trend was observed where sand content increased from 55.38 per cent to 73.15 per cent; silt and clay decreased from 25.52 per cent to 17.04 per cent and 18.90 per cent to 9.81 per cent, respectively (Table 26).

Inquisition of the data in the Table 27 revealed that reclaimed site (12 years old) in Quercus forest had higher proportion of sand (79.94 per cent) in 0-20 cm soil depth than the mine free site (44.97 per cent). In reclaimed site, silt and clay contents of soil in 0-20 cm soil depth decreased from 34.29 per cent to 10.08 per cent and 20.74 per cent to 9.98 per cent, respectively. Similar trend was recorded for lower soil depth (0-40 cm) where sand content in reclaimed site increased from 48.79 per cent to 82.06 per cent; silt and clay content decreased from 29.36 per cent to 9.74 and 21.85 per cent to 8.20 per cent, respectively.

Table 28 shows that the sand content of soil in dry mixed deciduous forest was 52.48 per cent and 51.79 per cent on western and northern aspect, respectively, whereas, the sand content in abandoned sites of different ages (5,10, 18 years) in this vegetation zone varied from 71.36 per cent to 78.16 per cent. The silt and sand content of soil on the western and northern aspect was (28.25 per cent, 27.69 per cent) and (19.27 per cent, 20.52 per cent) respectively, whereas the silt and clay content in the abandoned sites ranged from 15.46 per cent to 20.20 per cent and 6.38 per cent to 8.44 per cent, respectively. Further, Table 28 reveals that the sand content decreased; silt and clay content increased with the increase in abandonment from 5 to 18 years.

In Moist Shiwalik Sal forest the bulk density of soil (0-20 cm) in mine free site was 1.18 $Mgm^{-3}$, whereas, the bulk density of the reclaimed site was 1.53 $Mgm^{-3}$

(Table 29). Bulk density showed similar trend in the lower soil depth (20-40 cm) where it increased from 1.20 $Mgm^{-3}$ to 1.73 $Mgm^{-3}$ in reclaimed site. pH and electric conductivity (E.C) of the soil in the mine free site were 6.21 and 0.109 $dsm^{-1}$, respectively in 0-20 cm depth, whereas, in reclaimed site it was 8.52 and 0.128 $dsm^{-1}$, respectively. pH (6.36) and E.C (0.130 $dsm^{-1}$) of the soil in the mine free site were likewise, lower than the reclaimed site (8.66 and 0.143 $dsm^{-1}$), respectively for 20-40 cm soil depth. In mine free site (0-20 cm) organic carbon, nitrogen, phosphorus and potassium of soil was recorded to be 1.22 per cent, 352.72 kg/ha, 42.22 kg/ha and 276.40 kg/ha, respectively. At the respective soil depth in the reclaimed site these parameters of soil showed values as 0.86 per cent, 196.80 kg/ha, 32.46 kg/ha and 178.35 kg/ha, respectively. Likewise, in the lower soil depth (20-40 cm) organic carbon and macro- nutrients (N, P, K) recorded lower values in reclaimed site than mine free site (Table 29).

An appraisal of the data in Table 30 explicated that in Quercus forest the bulk density of soil in mine free site (1.12 $Mgm^{-3}$) for 0-20 cm depth was lower than the reclaimed site (1.57 $Mgm^{-3}$). The bulk density of 20-40 cm soil depth followed the same trend. pH and E.C of the soil in the mine free site (0-20 cm) were 7.68 and 0.132 $dsm^{-1}$, respectively, whereas, in reclaimed site the pH and E.C were 8.24 and 0.146 $dsm^{-1}$, respectively. Likewise, in the lower soil depth (20-40 cm), pH (8.32) and E.C (0.162 $dsm^{-1}$) of the reclaimed site showed higher values compared to mine free site (7.90 and 0.138 $dsm^{-1}$), respectively. In mine free site at (0-20 cm) soil depth organic carbon, nitrogen, phosphorus and potassium showed higher values (1.20 per cent, 336.24 kg/ha, 40.30 kg/ha and 263.20 kg/ha, respectively) in comparison to reclaimed site (0.62 per cent, 188.59 kg/ha, 29.11 kg/ha and 173.60 kg/ha, respectively). Likewise, at 20-40 cm soil depth levels of organic carbon and macro nutrients (N, P, and K) had lower values for reclaimed site than mine free site.

Table 31 shows that bulk density of the soil on the western (1.21 $Mgm^{-3}$) and northern (1.17 $Mgm^{-3}$) aspect in the dry mixed deciduous forest was lower than the abandoned sites of different ages (5, 10, 18 years). It was evident from the Table that the bulk density decreased from 1.54 $Mgm^{-3}$ to 1.38 $Mgm^{-3}$ with the increase in term of abandonment from 5 to 18 years. pH (7.80 and 7.76) and E.C (0.135 $dsm^{-1}$ and 0.136 $dsm^{-1}$) of the western and northern aspect, respectively were lower than the pH and E.C. of the abandoned sites, which ranged from 8.15 to 8.36 and 0.139 $dsm^{-1}$ to 0.147 $dsm^{-1}$, respectively. Further, Table 31 reveals that pH and E.C showed decreasing trend with the increase in age of abandoned mine. The values of soil organic carbon, nitrogen, potassium and phosphorus of dry mixed deciduous forest on the western aspect were 1.10 per cent, 329.76 kg/ha, 37.74 kg/ha and 185.69 kg/ha, respectively, likewise on northern aspect the values recorded for these parameters were1.15 percent, 336.74 kg/ha, 375.98 kg/ha and 187.68 kg/ha, respectively. Whereas, the value of organic carbon, nitrogen, phosphorus and potassium of soil in the abandoned sites of age 5, 10 and 18 years ranged from 0.15 per cent to 0.56 per cent; 35.56 kg/ha to 65.69 kg/ha; 6.54 kg/ha to 14.08 kg/ha and 30.44 kg/ha to 45.28 kg/ha, respectively. The increase in level of organic carbon and macro-nutrients (N, P, K) with the increase in age of abandoned site from 5 to 18 years was also noticed (Table 31).

**Table 26:**

**Soil separates (%) in mine free zone and reclaimed sites under Moist Shiwalik Sal forest of district Sirmaur (H.P)**

| Soil separates | Mine free zone | | Reclaimed site | |
|---|---|---|---|---|
| | 0 -20 cm | 20 – 40 cm | 0 -20 cm | 20 – 40 cm |
| Sand | 47.37 | 55.38 | 62.45 | 73.15 |
| Silt | 35.50 | 25.52 | 26.06 | 17.04 |
| Clay | 17.13 | 18.90 | 11.49 | 09.81 |

**Table 27:**

**Soil separates (%) in mine free zone and reclaimed sites under Quercus forest of district Sirmaur (H.P.)**

| Soil separates | Mine free zone | | Reclaimed site | |
|---|---|---|---|---|
| | 0 -20 cm | 20 – 40 cm | 0 -20 cm | 20 – 40 cm |
| Sand | 44.97 | 48.79 | 79.94 | 82.06 |
| Silt | 34.29 | 29.36 | 10.08 | 09.74 |
| Clay | 20.74 | 21.85 | 09.98 | 08.20 |

**Table 28:**

**Soil separates (%) at 0 -20 cm depth in mine free zone and abandoned mined sites under dry mixed deciduous forest of district Sirmaur (H.P.)**

| Soil separates | Mine free zone | | Age of abandoned site (years) | | |
|---|---|---|---|---|---|
| | I* | II** | 5 | 10 | 18 |
| Sand | 52.48 | 51.79 | 78.16 | 72.09 | 71.36 |
| Silt | 28.25 | 27.69 | 15.46 | 20.07 | 20.20 |
| Clay | 19.27 | 20.52 | 06.38 | 07.84 | 08.44 |

I* = Western aspect
II** = Northern aspect

**Table 29:**
**Soil properties at different depths in mine free zone and reclaimed sites under Moist Shiwalik Sal forest of Sirmaur district (H.P.)**

| | Mine free zone | | Reclaimed site | |
|---|---|---|---|---|
| | 0 – 20 cm | 20 – 40 cm | 0 – 20 cm | 20 – 40 cm |
| Bulk density (Mgm$^{-3}$) | 1.18 | 1.20 | 1.53 | 1.73 |
| pH | 6.21 | 6.36 | 8.52 | 8.66 |
| E. C. (dsm$^{-1}$) | 0.109 | 0.130 | 0.128 | 0.143 |
| O. C. (%) | 1.22 | 0.95 | 0.86 | 0.69 |
| Nitrogen (kg/ha) | 352.72 | 338.80 | 196.80 | 168.30 |
| Phosphorus (kg/ha) | 42.22 | 34.12 | 32.46 | 26.60 |
| Potassium (kg/ha) | 276.40 | 296.80 | 178.35 | 190.40 |

**Table 30:**
**Soil properties at different depths in mine free zone and reclaimed sites under Quercus forest of Sirmaur district (H.P.)**

| | Mine free zone | | Reclaimed site | |
|---|---|---|---|---|
| | 0 – 20 cm | 20 – 40 cm | 0 – 20 cm | 20 – 40 cm |
| Bulk density (Mgm$^{-3}$) | 1.12 | 1.16 | 1.57 | 1.62 |
| pH | 7.68 | 7.90 | 8.24 | 8.32 |
| E. C. (dsm$^{-1}$) | 0.132 | 0.138 | 0.146 | 0.162 |
| O. C. (%) | 1.20 | 0.85 | 0.62 | 0.45 |
| Nitrogen (kg/ha) | 336.24 | 314.52 | 188.59 | 145.60 |
| Phosphorus (kg/ha) | 40.30 | 31.86 | 29.11 | 21.70 |
| Potassium (kg/ha) | 263.20 | 285.60 | 173.60 | 188.23 |

**Table 31:**
**Soil properties at 0 – 20 cm depth in mine free zone and abandoned mined sites of different ages under dry mixed deciduous forest Sirmaur district (H.P.)**

| | Mine free zone | | Age of abandoned site (years) | | |
|---|---|---|---|---|---|
| | I* | II** | 5 | 10 | 18 |
| Bulk density (Mgm$^{-3}$) | 1.21 | 1.17 | 1.54 | 1.42 | 1.38 |
| pH | 7.80 | 7.76 | 8.36 | 8.24 | 8.15 |
| E. C. (dsm$^{-1}$) | 0.135 | 0.136 | 0.147 | 0.138 | 0.139 |
| O.C. (%) | 1.10 | 1.15 | 0.15 | 0.35 | 0.56 |
| Nitrogen (kg/ha) | 329.76 | 336.74 | 35.56 | 52.74 | 65.69 |
| Phosphorus (kg/ha) | 37.74 | 37.98 | 06.54 | 10.72 | 14.08 |
| Potassium (kg/ha) | 185.69 | 187.68 | 30.44 | 38.71 | 45.28 |

I* = Western Aspect
II** = Northern aspect

# DISCUSSION

# CHAPTER-V
# DISCUSSION

Mining is an essential natural resource utilization process meant for economic development of the society but in the process it often affects the landmass severely and so the environment and the human life are face to face with gamut of unwarranted problems. It is imperative therefore to monitor and assess the extent of deterioration in the quality of environment and changes in vegetation in spatial and temporal manner through mining to formulate effective management strategies for future. In the light of above point of view, the study done in lime stone mined areas of district Sirmaur is discussed under the following sub-headings:

5.1. Survey of mined areas of district Sirmaur
5.2 Change in vegetation patterns
5.3 Comparison of physio-chemical characteristics of soil in mined and mine free areas.

## 5.1 Survey of mined areas of district Sirmaur

District Sirmaur in Himachal Pradesh nurtures limestone, sand, bajri and stone boulder mines. The major type among them is limestone mines. The total number of limestone mines identified in the district is 71. The lease period allotted to most of the mines for extracting the mineral is 20 years. However, in some cases it is as high as 40 years and as low as 5 years (Table 1). The area leased out for mining varies from 4 bighas to 874.70 bighas. Out of the total mines that have been identified 18 mines are permanently closed and 19 are temporarily closed. It was also recorded during survey that though some of mines are in operation from last two decades even then the degraded land area due to active mining barely ranged from 1.25 per cent to 38.29 per cent of the total leased out area. The mines more than 100 bighas, at present, show low percentage of land degradation due to mining. The extent of the degraded land in different mines is governed by factors like, low-grade material present in the mine, monetary constraints, shortage of labour, lack of machinery, etc. Further, the extent of the degraded land is low due to the extraction technique -'vertical earth cutting' which is suited when the tract is mountainous. The material is extracted comfortably and economically, without an abrupt increase in the area of extraction.

Few stone crushers are also operating in the district (Table 2).These crushers extract raw material from the river basins, which are private lands. Government land has been allotted only to one crusher for extracting raw material. Five permits have also been granted for extraction of sand from private river basins. The area allotted for extraction of sand varies from 19.15 to 238.50 bighas. Besides these, there are also some other areas from which limestone, sand, bajri and stones are extracted illegally. The name of the owners and other type of the information regarding these mines could not be ascertained due to people's resistance for disclosing any information.

Majority of the limestone mines that are recorded in district Sirmaur belonged to the class 1133 (Alkaline and calcareous, Non-stony, sandy and Very steep) of USDA classification for mine spoils (Table 3). The other classes of mine are 1143, 1132, 1233, 2233 and 1243.

In the mined areas of district Sirmaur, half of the male population represents the working force, implying that the potential of required manpower to carry work in mines is present locally. Conversely, the males in this area have employment source at their doorstep. It was noticed that the number of females in the age-class (15-45 years) were appreciably higher as compared to young and old females (Table 4). Further, the demographic figures of the area reveal that the old people (>45 years) are less than infants \ children (0-15 years). However, present scenario of the population shows that these mines won't face any scarcity of mine- labours for at least another two decades. Though the working force in the area is likely to decrease based on the age-class presently available here. In general, it was also observed that in the mined areas the number of females were less than number of males (0.82:1), which is slightly lower than the female male ratio of 0.9:1 in district Sirmaur (Anon,2002).

Literacy in the district Sirmaur is 70.85 per cent and that of H.P. is 77.13 per cent (Anon, 2002), whereas, the average literacy in the mined areas of district Sirmaur is 57.25 per cent which is far below. Graduates constitute only a small proportion of the literates in the area (Table 5). The graduates are higher in Rajpura as compared to other two sections i.e. Sataun and Sangrah. Moreover, the literacy in Rajpura (61.71per cent) is higher than in other two sections. This can be attributed to high-income of people in Rajpura as compared to other two sections. Perhaps, this is the reason that less number of people are engaged in mines in Rajpura, which they consider only as a subsidiary source of income. The educational standard of the people in the mined area of district Sirmaur is of the level that they are forced to look for casual employment. Mining is such a viable option of employment for the people living here. With this type of income, the people of the area at present are far away from any kind of financial upliftment. Though the mines in the area provide people only the subsistence income yet 88.89 per cent of the people engaged in mines are working there for more than 5 years. The reason for this may be that people in these areas have low educational level, which suits only to casual employment.

It was recorded that, though, all the people living in the area do agriculture but some of them are also earning from professions like shop keeping, rural artisans, government and private entrepreneurship and others (local labours, contractors etc.). The data revealed that besides agriculture about half of the families are also working in mines (Table 6). Thus, with the presence of mines people have options to earn from different means to sustain their livelihood which was basically agriculture in absence of mines. These results are in conformity with Sikka *et al.* (1984), who reported that quarrying resulted in providing employment and income to the people. Shopkeepers have also flourished well in the area on account of mines. The notable feature was that females are prohibited by families to work in mines, though a part of agriculture is handled by them. Panwar (1999) also reported similar findings in mines of district Solan in Himachal Pradesh.

Majority of population in the mined area fall in the annual income group of Rs. 0.5-1.0 lakh, primarily due to employment in government or private sectors, other than mines (Table 7). Comparing the three sections in the mined areas of district Sirmaur in Rajpura 43.33 per cent people are earning more than Rs. 1 lakh annually, whereas, the number of people in this group in other sections varied from 16.66 per cent to 26.66 per cent which may be due to lesser percentage of people in government and private entrepreneurship in these sections as compared to Rajpura. A proportion of people also have a annual income less than Rs. 0.5 lakh which shows that the mines in the area has provided the people only the subsistence income.

People employed in mines are not earning substantial amount but paltry figure of Rs. 1306.92 – Rs. 1577.03 per month which is about 3/4$^{th}$ of the salary of casual labour getting in Himachal Pradesh (Anon, 2002). Low wages is the reason that 63.34 per cent of people working in mines consider mines for only subsidiary source of income in the mined areas of this district (Table 9). The percentage of families dependent on mines is more in Sataun (60.00per cent) and Sangrah (50.00per cent) only. People work in mines, only if they have spare time after completing their agricultural activities.

The data pertaining to change of income on account of mines in the mined areas of district Sirmaur revealed that people's income in this area has increased as a direct consequence of mining for only 40.00 per cent people (Table 10). This category of people has small land holding or more proportion of fallow lands or pastures (Ghasnis) in their total landholding. Therefore, the additional income from mines obviously increases their income. Erosion of agricultural lands on account of mining is responsible for the decrease in income for a small proportion (2.22 per cent), of population. About 57.78 per cent of the population either not associated in anyway with mining or earning low wages if working in mines, reported no change in income on account of mines.

People of the mined areas in district Sirmaur possess small agricultural landholding, 0.99 ha per family in mined areas, 2.28 ha per family in Himachal Pradesh (Anon, 2002) and ownership in mines as some of their lands fall under mines. The major proportion of the total land holding is unirrigated prohibiting thereby the cultivation of remunerative cash generating crop enterprises like vegetables, fruits etc (Table 11). These landholding represent fallow lands, wastelands, grass lands and rainfed agricultural lands. Thus, dependence of agriculture on rains force the local inhabitants to look for some subsidiary occupation during lean periods for sustaining their livelihood. To work in mines becomes an obvious choice because the limited rainfed agriculture cannot afford them enough produce sufficing their family needs for whole year. This trend was noted in all the sections of the mined areas in the district. It can be evinced from the result that mining is basically one of the job related activity of the people living here for getting partial remuneration to families. Majority of the people are casual labourers, without any ownership rights in mines (Table 11).

The demerits of mines as revealed by persons working in the mines in order of their decreasing preferences are: low wages, periodic closure of mines and low royalty. Lack of vocation and low educational level force them to depend on only labour oriented jobs, as a result of which good returns are not received by them (Table 12). Climatic disturbances and interference of government leads to periodic closure of mines. Proposed suggestions by people to overcome these demerits are increase in wages, increase in royalty, uninterrupted mining and continuous interaction of officials, workers and mine owners (Table 13).

Adverse effects of mining in the area are dust pollution, noise pollution, decrease in water level of natural water sources, increase in fallow lands, erosion of agricultural lands etc (Table 14). Increased dust pollution forces the people to collect fodder from far off places. Frequent plying of trucks on unmetalled roads in the mining areas, violation of mining norms and unmechanised mining are responsible for the increase in dust pollution in these areas. These results are in agreement with the work done by Panwar, 1999 who reported increase in dust pollution in the mined areas of district Solan in Himachal Pradesh.

Many natural resources in the area have dried up, some have become periodic or their flow has decreased. Panwar, 1999 also reported decrease in water levels in the mined area of district Solan. Decrease in level of natural water sources is not responsible for the decrease in agricultural production as most of the agricultural lands are rainfed. Though people have reported no change in cropping pattern yet they have shifted from their traditional agricultural crops to cash crops. This change in cropping pattern can be accounted for the subsidized seeds, fertilizers and other support being provided to farmers by agricultural department. Thus, mining has no role in changing the cropping pattern of this area.

Mining is expected to have a definite impact on flora and fauna yet the people reported no change in flora and fauna. This can be considered as ignorance of the people or they are not much bothered about the variations in flora and fauna and might be interested in monetary gains only (Table 14). Erosion of agricultural lands on account of mining is reported by majority (84.44 per cent) of the population. The erosion of agricultural lands may be due to mine spoils, dust settling, earth movement and blasting. Water pollution as reported by a section of population can be due to the surface runoff from mines, which brings along with it calcium and other minerals, into the water resources (Table 14). Mines are located along the roads in Sataun, blasting in mines and occasional landslides from the mines often lead to blockage of roads. Blasting in mines also damages the houses located near mines.

## 5.2 Change in vegetation pattern

Sirmaur district of Himachal Pradesh is known for Sal trees as chief economic species. Pure Sal forests are found in the belt on the Northern side of the main Shiwalik ridge and Southern side of the outer Himalayan range. The composition of the forests is governed by the abiotic factors viz. soil, aspect, altitude, topography, soil moisture and biotic interferences chiefly grazing and mining. Coincidently, these forests inhabit areas having limestone.

In the natural plant succession there is a continual change in the vegetation as a result of interaction of plant community and the habitat factor. The natural succession is inherently and inevitably progressive and the end product is climax. The succession is the progressive development of vegetation on the same site in course of time (Clements, 1916). In the present study, in order to understand the initial vegetation in the process of succession and reclamation processes in Sal forest 6 years old abandoned site and 13 years old reclaimed site was considered for study which revealed the following:

The presence of the *Wendlandia exserta* on the abandoned site is an indication of progressive succession as this tree often grows with Sal in shady places (Working plan, Forest working circle Nahan, H.P., 1976-1986). Clements (1916) contended that given indefinite time without disturbances to the community or the site, the plant communities in a given climatic region would approach to same composition and structure. If this hypothesis is followed then invasion of *Wendlandia exserta* on the abandoned site is an indication that *Shorea robusta*, which is climax species, is likely to invade the site with passage of time. Though the succession in an area always progresses to achieve original vegetation but as it may take many decades before fruitful results are obtained. It is further procrastinated on account of prevailing biotic interferences like grazing and fire. The other way to speed up the revegetation process in mined areas is to do artificial plantations to curtail time-gap in revegetating the area. Thirteen years old reclaimed site in moist Shiwalik Sal forest evaluated for vegetation performance revealed four trees (*Acacia catechu, Dalbergia sissoo, Wendlandia exserta, and Leuceana leucocephala*), whereas, in the undisturbed site of Sal forest, *Phoenix acaulis* and *Pyrus pashia* were the associate tree species with *Shorea robusta*.

Vegetation in the abandoned site was dominated by *Rumex hastatus* and *Eupatorium reveesii*. These species possess massive root system and are able to survive water and nutrient stresses which are the characteristic features of colonizers (Dwivedi, 1992). *Eupatorium odoratum* is a nurse crop for Sal natural regeneration in its early stages of development in Kamrup and Goalpara divisions in Assam (De, 1941). *Eupatorium reveesii* represented 88.09 per cent of total individuals of shrubs besides accounting for 64.49 per cent basal area of shrubs on the abandoned site. In the undisturbed site though this species was dominant among shrubs yet it accounted only for 45.14 per cent and 52.55 per cent of the density and basal area of shrubs, respectively.. The low percentage of density and the basal area of *Eupatorium reveesii* in the Sal forest as compared to abandoned site can be accounted for over head shade created by the Sal trees. *Eupatorium* spp. is a light demander (Papiya and Ramakrishnan, 2002, Mogali, 1981). This species can be called as pioneer species in this area as being present in the mine spoils of active mine zone. Moreover, it can be said that the site has reached consolidation stage following Graham (1955), who have identified different stages in the primary succession for mesophytes. In the reclaimed site five shrubs (*Eupatorium reveesii, Lantana camara, Woodfordia fruiticosa, Adhatoda vasica, Dodonea viscosa*) and three herbs (*Saccharum spontaneum, Fimbristylis rigidula, and Arundinella nepalensis*) were planted. These species are commonly used for the reclamation and stabilization of the mined areas. Soni *et al*, (1986) planted *Acacia catechu, Wendlandia exserta, Dalbergia sissoo, Woodfordia furiticosa, Adhatoda vasica, Lantana camara, Saccharum spontaneum* and various other species for the reclamation of mine spoils in Doon valley (Maldeota).

The species diversity of the reclaimed site was higher as compared to naturally growing Sal forest. Perhaps, this may be due to the plantation of diverse species in the reclaimed site. Moreover, in plantations the competition from abiotic variables especially light is not as critical as in fully developed Sal forest which hampers growth and development of understory vegetation. Soni *et al*, (1989) evaluated the diversity of plants on reclaimed surface mine areas and found that diversity of plants had increased significantly after 4 years of reclamation and is even higher than adjoining natural areas.

In the present study, plant diversity as well as basal area and density of trees, shrubs and herbs in the reclaimed site were high compared to abandoned site. This can be accounted for the management practices employed and improvement in the soil properties. Verma *et al,* (2004) reported that diversity of the ground flora was higher under the plantations compared to those in exposed mine overburden area. The species composition of herbaceous vegetation in the Sal forest revealed *Oplismenus compositus* as the prominent herb indicating that the site was moist which is in contrast with abandoned and reclaimed site.

Whittaker (1953) contented that in any particular habitat in a landscape, if the climax community may have been developed or may not have yet developed, the community goes through progressive development of parallel and interacting changes in environment and communities; succession. The end point of succession is climax, community of relatively stable species composition and steady state function, adapted to its habitat and essentially permanent in its habitat, if undisturbed. This hypothesis was followed for dry mixed deciduous forest to study the progression of a site towards climax. Three abandoned mines of different ages (5, 10 and 18 years) were considered for study. The knowledge of the dynamics of natural succession will be helpful for future ecological restoration of mined areas.

Clements (1916) stated a universal law that all bare places give rise to new communities except those, which present the most extreme condition of water, temperature, light or soil. The natural process of ecological rehabilitation is governed by micro-climate, soil properties, surrounding flora and disseminating efficiency of propagules (Gibson *et al*, 1985). For an ecosystem approach of rehabilitation process, it is necessary to understand the ecosystem structure, including the process of primary and secondary succession (Thomson *et al*, 1984, Nandeswar *et al*, 1995). The comparison of the vegetation on the abandoned sites of different ages can build an idea of revegetation process i.e. succession in dry mixed deciduous forest. Abandoned mined sites of different ages (5, 10, 18 years) revealed that *Eupatorium reveesii* was the dominant shrub on all the abandoned sites. This shrub can be considered as pioneer species in this zone.

*Eupatorium reveesii* was occasionally recorded on western aspect and was absent on northern aspect in dry mixed deciduous forest. More ever, it was noticed that the species number is increasing with the increase in term of site abandonment. Eighteen years old abandoned site is invaded by two tree species i.e. *Acacia catechu* and *Trema politoria* which are not yet fully grown on the site. The vegetation composition of the undisturbed dry mixed deciduous forest area surrounding these abandoned sites revealed that *Phoenix acaulis* was the prominent tree species (western aspect), on the northern aspect *Phoenix acaulis* and *Acacia catechu* dominated the site. Thus, it can be said that after 18 years of abandonment the site has reached consolidation stage following Graham (1955). Increase. in species number from 6 to 32 in the abandoned field of 1 and 4 years and more perennial species in the 4 years old abandoned field was reported by Abul fatih (1999).

Time is an important factor in succession and increase in diversity with the increase in age of mine spoils is an ordered phenomenon (Tilman, 1985, Jha and Singh 1991). The increased diversity may well increase the stability of the community and its ability to adapt the changes in climate or to exploit various micro environments in the habitat. The change in species diversity is an attribute of succession (Mac Arthur and Connell, 1966), who concluded that each species alters the environment in such a way that it can no longer grow as successfully as others. The forest community is never static. It is continuously changing in composition, structure and general characters. That means one set of species mix is replaced by another site in this process (Dwivedi, 1992). Comparing the three abandoned sites it can be concluded that species composition was changing with the increase in term of site abandonment. Donfack *et al*, (1995) reported that the vegetation changed continuously during the 35 years of field abandonment of formerly cultivated fields in dry tropical northern Cameroon. In the present study, comparison of the basal area and density of the vegetation on abandoned sites revealed both the parameters were also increasing with the increase in term of site abandonment. The increase in density and basal area of the species can be attributed to the improvement in soil characteristics (nutrients and soil texture) by the existing vegetation on these sites. The herbaceous vegetation of the dry mixed forests (western and northern aspect) comprised mostly grasses, whereas sedges and forbs dominated the herbaceous vegetation in abandoned sites. If we consider that species composition and species diversity represent structural features of the community and that density and basal area is a functional attribute then it is clear that both structurally and functionally that community has progressed gradually and continuously. Likewise findings were reported by Odum (1960) while estimating the organic production and turn over in old field succession. However one cannot predict with certainty how much time it will take a site to reach the climax as there are tremendous operational difficulties. A truly definite test would require an experiment of decades. For example in the Boreal forests of the Northern Hemisphere, the influence of early successional trees, such as *Betula papyrifera*, can extend for 50-100 years after a clearing (Botkin, 1981).

It was recorded during the survey that Quercus forests were also growing in limestone mined area. These forests occured on the northern aspect of Kamroo Bharli dhar and Trilodhar on northern slopes in Sataun section. Throughout, its distribution the composition is considerably changed by biotic interferences like grazing, burning and merciless lopping.*Quercus leucotricophora* grows gregariously and is frequently associated with *Quercus dilatata,Cedrus deodara* and *Pinus wallichiana* towards the upper limit (2000-2300m) and *Pinus roxburghii* and *Quercus glauca* towards the lower limit (800-1000m). *Rhododendron arboretum, Lyonia ovalifolia, Pyrus pashia, Myria nagi* etc. are the common associates in its normal zone of distribution (Khanna, 1981). This type of forest is definitely a climatic climax.

To understand the revegetation and reclamation processes in this forest zone 8 year old abandoned site and 12 years old reclaimed site were considered for study.

Plant communities are disturbed by the mechanisms which limit the plant biomass by causing its partial or total destruction. In forest, disturbances arise either from the damage or death of the trees resulting in a gap in the canopy and this initiates a successional process known as forest growth cycle (Burslem, 2004). In the present study, trees were absent on 8 years old abandoned site. *Quercus leucotricophora* requires moist site and overhead shade for germination (Luna, 1996). This might be the reason that not a single seedling of *Quercus leucotricophora* has inhabited the site even after 8 years of abandonment or the soil substrate has not improved to an extent to sustain this species. Due to mining, natural biotic vegetal set up is lost which causes retrogression, decrease in biodiversity and increase in dominance of uneconomic species. With continued biotic protection together with rehabilitation measures and protection against grazing and cutting of grasses and trees the retrogression will come to stand still. The problem of reclaiming mined lands varies according to topography, climate and the type of material present in the overburden. However, an artificial reclamation stabilizes the ecosystem much faster than the natural revegetation process. Twelve years old reclaimed mined site in Quercus forest revealed 3 trees (*Bauhinia variegata*, *Populus deltoides* and *Robinia pseudocasia*) and 3 shrubs (*Berberis lycium*, *Dabregeasia hypoleuca* and *Eupatorium reveesii*). All the other species (Table 25) present on the reclaimed site had naturally inhabited the site with the passage of time. The species planted on this site are often used for the stabilization and reclamation of mined areas. Soni *et al* (1989) planted *Bauhinia variegata*, *Populus deltoides* and *Robinia pseudocasia*, *Pinus roxburghii* and various others tree species on mined site in Durmala.

In the present study, *Pyrus pashia* was the associate tree species in Quercus forest. Nine shrubs and ten herbs formed the understory vegetation (Table 23) with basal area 6323.92 $m^2$/ha. *Leptodermis lanceolata*, *Rhamnus virgatus* and *Myrsine africana* were the prominent shrubs, while *Berberis lycium* was occasionally reported. Our results confirm the reports given by Qaiser *et al* (1993) who reported that the undergrowth of *Quercus leucotricophora* includes shrubs like *Berberis lycium* and *Myrsine africana*. The proportion of perennial herbs was higher than the annuals in the Quercus forest giving an indication of stable community. *Eupatorium reveesii* and *Rumex hastatus* dominated the abandoned site. These species have the characteristic features of colonizers as discussed earlier. *Eupatorium reveesii* besides representing 99.27 per cent of the total individuals accounted for 96.35 per cent of the total basal area of the shrubs in the abandoned site, compared to 9.50 per cent and 5.52 per cent of the density and basal area of shrubs, respectively, in the Quercus forest. Likewise, the abandoned site in Sal forest this species can be called as pioneer species. It is likely that with prolonged abandonment this species may improve the soil conditions making it suitable for the establishment of trees like *Quercus leucotricophora*. Iven (1974) concluded that *Eupatorium odoratum* acts as a protective crop in early stages of tree establishment. An early successional species alters the conditions or the availability of the resources in a habitat that the entry of new species is possible, a process known as facilitation (Connell and Slayter, 1977). *Eupatorium reveesii*, a light demander species (Papiya, 2000), is rare in Quercus forest in Sirmaur, compared to the abandoned site where it is the dominant species. This can be attributed to overhead shade and competition with other species in Quercus forest unlike the abandoned site. The another reason that *Eupatorium reveesii* has become rare in Quercus forest is that, being a pioneer species it has been replaced by other species with the development of the community towards the climax. Following Graham (1955) who have identified different successional stages for mesophytes it can be said that the site is in primary stage (pioneer stage) of succession compared to abandoned site in Sal forest, which is at the consolidation stage only after 6 years. Though the same pioneer species (*Eupatorium reveesii*) dominates both the sites yet, they differ in the stages of succession. This may be due to the difference in edaphic factors and micro-climate of the two sites. According to Spurr and Barnes (1980) there is no set time period for each stage to begin and end. One stage may occupy the site for long time at one site and less at another. The community composition on the two abandoned sites in the two zones i.e. Sal and Quercus is also due to variability of site conditions of the individual mine site. According to Hulsct (1978), the substrate conditions on individual mine site acts as an environmental sieve and a relationship between variable substrate and variable floristic composition is possible (Glenn-Lewin, 1980).

Shrubs accounted for 73.71 per cent of the total basal area of reclaimed site in Quercus forest zone. *Eupatorium reveesii* was the dominant species on the reclaimed site. The basal area of this species alone was more than the combined basal area of all the trees, shrubs and herbs. This can be attributed to high regeneration capacity of the species (Mogali and Hosmani, 1981). In the reclaimed site, species diversity was high as compared to the abandoned site. This is due to the artificial plantations, management practices adopted and protection against grazing and other biotic factors in the reclaimed site. Though no herbaceous vegetation was planted on this site yet, 2 grasses and 5 forbs have inhabited the site. Mostly the herbs are annual. This gives an indication that the process of ecosystem development has started. Brenner (1984) experienced that if ultimate objective of reclamation is to create a diverse and sable ecosystem then reclamation should be designed to stabilize the site which providing a suitable habitat for natural succession.

From the above discussion, it is evident that with the modification of physical . environment, the communities are under progressive succession. However, it is difficult to predict with certainty of time it will take to manifest itself into the climax. Hence, to make any conclusive statement regarding progression of serial stage at present requires a long time observation. It can further be appraised that though reclamation increases green cover rapidly, but divert the natural succession process compared to naturally revegetated abandoned site.

## 5.3 Physico-chemical characteristics of mined and mine free areas:

The physico-chemical characteristics are important for defining limitations of vegetal establishment (Dhruvnarayan *et al.,* 1987). Taking this consideration in view, the physico-chemical characteristics of soils in the limestone mined sites are discussed below:

### 5.3.1 Physical characteristics:

In the present study, it was recorded that soils of reclaimed sites in Moist Shiwalik Sal forest and Quercus forest had higher proportion of sand at both the soil depths (0-20 and 20-40 cm) compared to mine free zone at respective depths (Tables 26&27). The clay content of the soil in the reclaimed sites was less in both soil depths as compared to mine free zone (Sal and Quercus). The reason for this is that on account of mining lower soil horizons are exposed which are coarser in nature and the mine spoil is a mixture of rock fragment, and sub- soil particles. Accumulation of organic matter due to broad leaved species and its simultaneous decomposition over the years is another reason for reduced sand content in the mine free zone. Soni *et al* 1989 also reported that mining increase the sand percent and decrease the clay percent in soil. The bulk density of the soil in mine free zone of Sal and Quercus forest was lower at both soil depths compared to reclaimed sites. The increase in bulk density of the soil in reclaimed sites can be attributed to high percentage of sand and less organic matter in the soils compared to mine free areas (Sal and Quercus forest). Mine spoils have higher bulk density and coarse fragment, lower porosity, clay content and water holding capacity than reference soils (Masoodi, 1999).

The comparison of the physical properties of soil in the dry mixed deciduous forest and abandoned mined sites of different ages revealed that even after 18 years of abandonment the sand content was higher and clay content lower in the soil than the mine free areas of both western and northern aspect (Table 28). Dadhwal and Singh (1993) reported that mining increases the sand content and decrease the clay content of soils. However, it was evident that with the increase in abandonment from 5 to 18 years sand content of soil decreased and clay content increased marginally. The coarse fragments are negatively co-related and finer fractions are positively co-related with the age of mine soil. (Banerjee *et al*, 1997). The bulk density of the soil in abandoned sites was more than the mine free sites (western and northern aspects). However, the bulk density showed decreasing trend with the increase in period of abandonment. This can be attributed to increase in clay content due to weathering, increase in species diversity and organic matter accumulation with the increase in term of abandonment. The increasing trend in the water capacity (decreasing bulk density) with age is a clear indication of gradual stability of the mine spoils and the increase of finer fraction i.e. clay with age indicates the development of soil processes.

### 5.3.2 Chemical characteristics:

The data pertaining to chemical characteristics of soils in Moist Shiwalik Sal forest, Quercus forest and the reclaimed sites in these forests presented in Table 29 & 30 revealed that pH and electric conductivity (E.C) of the soil in mine free areas was less than the reclaimed sites at both soil depths. The increased pH and E.C of the soil in the reclaimed sites gives an indication that it has high quantities of salts and exchangeable bases. Soni *et al* (1989) analyzed the chemical characteristics of mine soil at Maldeota and found that pH and E.C of the mine soil was higher than the soils of undisturbed adjacent forest. It could further be ascertained that macro-nutrients viz. N, P and K and organic carbon had decreased on account of mining. The percentage of macro-nutrients and organic carbon was higher in mine free area (Sal and Quercus forest) compared to reclaimed sites at both depths (Table 29 & 30). The loss of vegetation cover and top soil layer on account of mining is the cause of depletion of the nutrients and organic carbon in the reclaimed site. Similar work was reported by Panwar (1999) who revealed that mining leads to depletion of nutrient contents and organic matter.

The chemical characteristics of the soil in the abandoned sites of different ages (5, 10 and 18 years) revealed that pH and E.C decreased with the increase in age of mine abandonment (Table 31). Berendse *et al* (1998) also reported while studying succession in coastal dune slacks that pH decreases with the age. The E.C was almost same after 18 years of abandonment as that of native forest indicating that the problem of salinity is removed much earlier than alkalinity and nutrient deficiency. The organic carbon content has increased from 0.15 per cent to 0.56 per cent with the increase in age of mine abandonment. Though nitrogen, phosphorus and potassium has also increased with the increase in term of mine abandonment but, the values of organic carbon and macro nutrients (N, P and K) are still lower than the native forest. The increase in organic carbon and nutrients with age may be perhaps due to increased vegetal cover and simultaneous decomposition processes. Banerjee *et al*, 1997 reported that the nutrient content and organic carbon increases with increase in age of mine spoil. Several other workers such as Wali (1987) in North Dakota, Russell and La Roi (1986) in Alberta and Fyles *et al* (1985) in South Eastern British Columbia have reported increased in nitrogen and phosphorus with the age of mine spoil. The organic carbon and the nutrient content of the soil in reclaimed sites of Sal and Quercus forest was higher compared to naturally re-vegetated sites. Perhaps, this is because of the perennial vegetation growing on the reclaimed site. However, as assumed by Schafer *et al* (1980) within a few decades many properties of the mine soil may approximate to those of natural soils. Soil structure formation and increase in soil organic matter and nutrients overtime may improve the suitability of mine soils for good plant growth.

Present results therefore, indicate the reclamation helps in enrichment of soil and increase the moisture content and improvement of other properties of mine spoils in short time compared to naturally revegetated abandoned sites.

# SUMMARY AND CONCLUSION

# CHAPTER-VI

# SUMMARY AND CONCLUSIONS

The present investigation entitled "**Appraisal of vegetation status in mined areas of district Sirmaurin Himachal Pradesh**" was conducted during the year 2005. For the survey, whole district was divided into three sections viz. Rajgarh, Sangrah, and Sataun on the basis of concentration of mines in these areas. Socio-economic survey was carried out by interviewing the selected families. Sal forest, Dry mixed deciduous forest and Quercus forest areas were studied for detailed vegetation analysis. These forests are located at a distance of 60, 70 and 88 kms from Nahan, respectively, at an elevation of 780-840 m, 1200-1250 m and 1700-1725 m above mean sea level, respectively. During survey composite soil samples from 0-40 cm soil depth were collected for each mine for USDA classification. However, in sites selected for vegetation analysis, composite soil samples were taken form 0-20 cm and 20-40 cm depths. In abandoned mines of the dry mixed deciduous forest soil samples could be taken from 0-20 cm depth alone as there was hard pan in lower horizon of soil. Composite soil samples of the sites selected for vegetation analysis were analyzed for pH, E.C., N, P, K and organic carbon. Besides, this bulk density and soil separates were also determined.

The salient features of the present investigation are summarized below:

## 6.1 Survey of mined areas of district Sirmaur

Limestone mines are the prominent type of mines in district Sirmaur. The number of limestone mines is 71, out of which 18 mines are permanently closed and 19 are temporarily closed. The total area under the limestone mines is 7057.49 bighas (5.24 sq. km). The mines are generally leased for 20 years. Though some of mines are operating from last two decades even then the degraded land area due to active mining barely ranged from 1.25 per cent to 38.29 per cent of the total leased out area. Few stone crushers are also operating in the district. Five permits have also been granted for extraction of sand from private river basins. The areas allotted for extraction of sand varies from 19.15 to 238.50 bighas. Besides these, there are also some areas from which limestone, sand, bajri and stones are extracted illegally.

Soil analysis as per USDA method for classification mine spoils showed that most of the mines in this area are alkaline and calcareous, non-stony, sandy and very steep falling under 1133 USDA class. Some other types of mines were also identified falling under 1143, 1132, 1233, 2233 and 1243 USDA class.

In the mined areas of district Sirmaur, half of the male population represented the working force, implying that the potential of required manpower to carry work in mines is present locally. The number of females in the age-class (15-45 years) was higher as compared to young and old females. Further, the demographic figures of the area reveal that the old people (>45 years) are less than infants \ children (0-15 years). In general, it was observed that the number of females was less than number of males (0.82:1) in the mined areas. The average literacy in the mined areas of district Sirmaur is 57.25 per cent. In this area graduates constitute only a small proportion of the literates. People of the mined areas in district Sirmaur possess small agricultural landholding, 0.99 ha per family. The major proportion of the total land holding is unirrigated prohibiting thereby the cultivation of remunerative cash generating crop enterprises like vegetables, fruits etc. Besides, agriculture about half of the families in these areas are working in mines. Majority of the people are casual labourers, without any ownership rights in mines. People employed in mines are earning only a paltry Rs. 1306.92 – Rs. 1577.03 per month, even then 88.89 per cent of the people engaged in mines are working there for more than 5 years. The notable feature was that females are prohibited by families to work in mines. The work force in these mines is unhappy and discouraged on account of low wages, periodic closure of mines and low royalty. Due to employment in government or private sectors, other than mines, majority of population in the mined area fall in the annual income group of Rs. 0.5-1.0 lakh. Income in this area has increased as a direct consequence of mining for only 40.00 percent of the people. Pollution in the form of dust, noise and water is also met herewith. Other adverse effects of mining noticed in this area are decrease in level of natural water sources, increase in fallow lands, erosion of agricultural lands etc,

## 6.2 Change in vegetation pattern

On the abandoned site, in the moist Sal forest zone, the presence of the *Wendlandia exserta* is an indication of progressive succession. *Acacia catechu, Dalbergia sissoo, Wendlandia exserta, and Leuceana leucocephala* were growing on the thirteen years old reclaimed site in moist Shiwalik Sal forest, whereas, in the undisturbed site of Sal forest, *Phoenix acaulis* and *Pyrus pashia* were the associate tree species with *Shorea robusta*.

Vegetation in the abandoned site of moist Shiwalik Sal forest was dominated by *Rumex hastatus* and *Eupatorium reveesii*. The latter represented 88.09 per cent of total individuals of shrubs besides accounting for 64.49 per cent basal area of shrubs on the abandoned site. This species was also dominant among shrubs in the undisturbed site of Sal forest zone but it accounted only for 45.14 per cent and 52.55 per cent of the density and basal area of shrubs, respectively. This species was a pioneer species of mined areas. In the reclaimed site five shrubs (*Eupatorium reveesii, Lantana camara, Woodfordia fruiticosa, Adhatoda vasica, Dodonea viscosa*) and three herbs (*Saccharum spontaneum, Fimbristylis rigidula, and Arundinella nepalensis*) were planted. The species diversity of the reclaimed site was higher as compared to naturally growing Sal forest. Plant diversity as well as basal area and density of trees, shrubs and herbs in the reclaimed site were also high compared to abandoned site.

Abandoned mined sites of different ages (5, 10, 18 years) in the dry mixed deciduous forest revealed that *Eupatorium reveesii* was the dominant shrub on all the abandoned sites. This shrub was a also pioneer species in this zone. *Eupatorium reveesii* was occasionally found on western aspect and was absent on northern aspect in undisturbed dry mixed deciduous forest. Two tree species, showing stunted growth, i.e. *Acacia catechu* and *Trema politoria* have invaded the eighteen years old abandoned site in dry nixed deciduous forest. The vegetation composition of the undisturbed dry mixed deciduous forest area surrounding these abandoned sites revealed that *Phoenix acaulis* was the prominent tree species (western aspect) and on the northern aspect *Phoenix acaulis* and *Acacia catechu* dominated the site. Species composition was changing (annuals being replaced by perennials and more diverse forms); basal area and density of the vegetation were increasing with the increase in term of site abandonment. The herbaceous vegetation of the dry mixed forests (western & northern aspect) comprised mostly grasses, whereas sedges and forbs dominated the herbaceous vegetation in abandoned sites.

In Quercus forest zone, no trees were recorded on the abandoned site even after 8 years. 3 trees (*Bauhinia variegata*, *Populus deltoides* and *Robinia pseudocasia*) and 3 shrubs (*Berberis lycium*, *Dabregeasia hypoleuca* and *Eupatorium reveesii*) were growing on 12 years old reclaimed mine in Quercus forest. *Pyrus pashia* was the associate tree species in undisturbed Quercus forest; 9 shrubs and 10 herbs forming the understory vegetation with basal area as 6323.92 $m^2$/ha. *Eupatorium reveesii* and *Rumex hastatus* dominated the abandoned site in this zone. Reclaimed site was dominated by *Eupatorium reveesii* alone. *Eupatorium reveesii*, a light demander species, is rare in Quercus forest in Sirmaur. *Eupatorium reveesii* besides representing 99.27 per cent of the total individuals accounted for 96.35 per cent of the total basal area of the shrubs in the abandoned site, compared to 9.50 per cent and 5.52 per cent of the density and basal area of shrubs, respectively, in the Quercus forest. The basal area of this species alone was more than the combined basal area of all the trees, shrubs and herbs in the reclaimed site. *Eupatorium reveesii* is pioneer species in this forest zone. Though the same pioneer species (*Eupatorium reveesii*) dominated the abandoned sites in two different forest zones (Sal and Quercus) yet, they differ in the stages of succession. Species diversity of the reclaimed site was high as compared to the abandoned site.

## 5.3 Physico–chemical characteristics of mined and mine free areas:

The study revealed that mining had increased sand per cent bulk density, pH and electric conductivity and decreased clay per cent, macro-nutrients viz. N, P and K and organic carbon of soils in Moist Shiwalik Sal forest and Quercus forest.

In the dry mixed deciduous forest, abandoned mined site of different ages revealed that even after 18 years of abandonment the sand content was higher and clay content was lower in the soil than the mine free zones of both western and northern aspect. It was also observed that with the increase in age from 5 to 18 years sand content of soil decreased and clay content increased marginally. The bulk density, pH and E.C. of the soil in abandoned sites were more than the mine free sites (western and northern aspects). However, these parameters showed decreasing trend with the increase in period of abandonment. The organic carbon and the macro nutrients (N, P, K) content has increased with the increase in age of mine abandonment.

# CONCLUSION

On the basis of findings in the present investigation following conclusions can be reasonably put forth in relation to mines in district Sirmaur, Himachal Pradesh:

- The major type of mining in district Sirmaur is limestone, covering 0.19 per cent of the total land area of district. Till date 8.89% of the total area of these mines is under 'active mining'. Most of the mines fall in the 1133 USDA class of mine spoils having alkaline and calcareous soil with pH range of 7.54 to 8.20, sandy and slope above 70 per cent.

- These mines have given an employment opportunity to local people. But, these are yet to enhance their economic status.

- Noise and dust pollution, decrease in natural water sources and erosion of agricultural lands is sequel to emergence of mines in this area.

- Revegetation process in abandoned mined sites under Shiwalik Sal forest and Quercus forest zones are showing progressive succession, though it is difficult to predict with certainty the time it will take to restore original flora.

- Natural succession in mines has shown increasing trend in species diversity, density of vegetation and basal cover of shrubs and herbs with the increase in term of site abandonment.

- Artificial regeneration of mines through plantations is better way to re-green them in short tenure. but the type of plant community established is altogether different from the otherwise long term natural succession process.

- Soil properties of the mined sites will approximate to the natural soils of the area with the passage of time as the revegetation process will progress. However, the improvement in soil structure and nutrients was faster in reclaimed mines as compared to abandoned mines.

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# CHAPTER-VII

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# APPENDICES

**Annexure-1**

# Socio-economic survey format

| | |
|---|---|
| **1. Name of the farmer** | |
| **2. Village** | |
| **3. Address** | |

**4. Family size (number):-**

Male-
Female-
Total:-

**5. Age composition (Years):-**

| Sex | 0 -15 | 15 – 45 | > 45 |
|---|---|---|---|
| Male | | | |
| Female | | | |

**6. Occupation of the family members:-**

| S.No | Specification | No. | S.No | Specification | No. |
|---|---|---|---|---|---|
| 1 | School going | | 5 | Shopkeeper | |
| 2 | In-service | | 6 | Mining | |
| 3 | Agriculture | | 7 | Any other specify | |
| 4 | Rural artisans | | | | |

**7. Annual income of family:-**

☐ >50,000 ☐ 50,000-1,00,000 ☐ >1,00,000

**7(a) Income of family from mining/mining land:-**

**7(b) Mining as a source of family income:-**

☐ Subsidary

☐ Main

**7(c) Livestock ownership:-**

Cows ☐ Buffaloes ☐ Sheep/goat ☐ Mules ☐

Any other (specify) ☐

**7(d) Income from livestock:-**

**8. Educational status of family:-**

☐ Illiterate ☐ Upto primary ☐ Upto middle ☐ Upto matriculation ☐ 10+2/Diploma

☐ Graduate and above

**9. Are you a land owner or landless:-**

**9(a) Total land holding (bighas):-**

Irrigated -
Unirrigated-

**10. Ownership of mining land (Yes/No)**
If yes specify area and type of mining:-

**11. Do you mine the land or extend its contract to outsiders? If yes, what are the conditions laid down for the contract?**

**12. Gender specification of the mining**

(a) List out activities of mining where women are engaged

(b) List out activities of mining where men are engaged

**13. Since how many years you are engaged in mining**

☐<5 years ☐ >5 years

**14. Are you facing problems in continuation of mining as a source of income? If yes what are the problems (specify):-**

**14(a) What are the possible solutions to the problems suggested by you?**

**15. What was the economic condition in the**

(i) Past

(ii) Present

**15(a) Do you think that mining has caused any change in your income?**

## 16. Impact of mining on migration

**Have you ever migrated from your ancestral home? If yes, tell reasons.**

**(a) Ecological factors:-**

1. Due to degradation of agricultural lands by way of mining
2. Dust problem
3. Noise pollution
4. Fodder scarcity
5. Air pollution
6. Any other or combination of these reasons

**(b) Social factors:-**

1. Sub-division of land holdings
2. Disintegration of family (Joint/Nuclear)
3. Land allotment by government in lieu of mining land.
4. Any other (specify)

**(c) Economic factors**

1. Employment avenues
2. Urban migration for education and better economy
3. Availability of productive lands
4. Migration to mining land areas for economic gains
5. Any other (specify)

## 17. Impact on agricultural lands

**17(a)** Have you observed any fall in agricultural productivity? If yes, please specify the crops and productivity* levels.

| S.NO. | Crop | Before mining | After mining |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

* Productivity $ha^{-1}$

17(b) If fall in productivity levels of agricultural lands are observed, then what are the reasons?

- Mining
- Abandoned land holdings
- Any other specify

**18. Cropping pattern before mining (species)**

**18(a) Cropping pattern after mining (species)**

## 19. Impact on environmental settings

**A. Impact on flora**

| Dominant tree species | |
|---|---|
| **Before Mining** | **After Mining** |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

**A.1. If any species is extinct, please specify the reasons and impact of extinction on your livelihood avenues**

**B. Impact on fauna**

| Dominant Animal species | |
|---|---|
| **Before Mining** | **After Mining** |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

**B.1. If any species is extinct, please specify the reasons and impact of extinction on your livelihood avenues**

**B. Impact on ecological aspects**

| Particulars | Impact after mining | | |
|---|---|---|---|
| | **Increase** | **Decrease** | **No change** |
| Noise pollution | | | |
| Dust pollution | | | |
| Water availability | | | |
| Agricultural productivity | | | |
| Fallow lands | | | |

# Personal Profile

**Name :** Syed Mubashir Hanief

**Father's Name :** Mr. Mohammad Hanief

**Permanent Address:** 160-Nasheman, Devdibagh, Badamwari, Hawal, Srinagar, Kashmir (J&K)

**Date of birth:** 09-06-1979

**Educational Qualification:**

| Class | Board/University | Percentage | Subjects | Year of Passing |
|---|---|---|---|---|
| Matric | J&K BOSE | 53.4 | Eng. Math. Science. Etc | 1994 |
| 10+2 | J&K BOSE | 63.66 | Eng. Phy.Chem. Bot. Zool. | 1996 |
| B.Sc (Forty.) | Dr.Y.S.Parmar University of Horticulture & Forestry Nauni Solan (H.P) | 65.4 | All forestry subjects | 2002 |
| M.Sc (Forty.) | Dr.Y.S.Parmar University of Horticulture & Forestry Nauni Solan (H.P) | 70.8 | Specialization in Silviculture | 2005 |

**M.Sc. Thesis Title:** "Appraisal of vegetation status in mined areas of district Sirmaur in Himachal Pradesh"

## Declaration

I do hereby declare that all the above-furnished information is correct and true to best of my knowledge.

**Syed Mubashir Hanief**

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| | | |
|---|---|---|
| **Title of Thesis** | : | **"Appraisal of vegetation status in mined area of Sirmaur district in Himachal Pradesh"** |
| **Name of the Student** | : | Syed Mubashir Hanief |
| **Admission Number** | : | F-2002-03-M |
| **Major Advisor** | : | Dr. Bhupender Gupta (Assoc. Professor) |
| **Major Field** | : | Silviculture |
| **Minor Field(s)** | : | i) Tree Improvement and Genetic Recourses<br>ii) Soil Science |
| **Degree Awarded** | : | M.Sc. (Silviculture) |
| **Year of Award of Degree** | : | 2005 |
| **No. of pages in thesis** | : | 97 + v |
| **No. of words in Abstract** | : | 285 |

## ABSTRACT

The present investigation was carried out during the year 2005 to study then extent of mining, socio-economic status of the people in the mined areas, revegetation and reclamation processes in the abandoned mines of district Sirmaur in Himachal Pradesh. The whole district was divided into 3 sections viz. Rajgarh, Sangrah and Sataun for conducting survey which revealed the presence of 71 limestone mines covering an area of 5.24 sq. km. Few mines of sand, bajri and stones are also operational in the area. Mining in this area has provided employment to the local people. However, this has failed to increase their economic status. Adverse effects of mining in this area are observed in form of dust and noise pollution, decrease in water sources, erosion of agricultural lands etc. Vegetational analysis in abandoned and reclaimed mines located in Sal, Quercus and Dry mixed deciduous forest revealed that diverse shrubs and herbs have invaded these mines. Trees were however recorded only in few sites. Abandoned mine in Sal forest showed the emergence of trees in it after 3 years of abandonment, whereas, it took around 15 years for trees to inhabit abandoned mine in Dry mixed deciduous forest, while no trees could be traced out in 8 years old abandoned mine in Quercus forest. It was also recorded that increase in term of abandonment of mine increases functional parameters like density and basal area of vegetation. *Eupatorium reveesii* was found as pioneer species in all mined sites of the three different vegetational zones. Artificial plantation in abandoned mines has improved the physico-chemical properties of soils, but the soils in these reclaimed sites are still poorer to mine free areas. Increase in term of abandonment also improves the soil characteristics.

**Signature of Major Advisor** **Signature of the Student**

**Countersigned**

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