CHAPTER 4

IMPACT OF SUBSIDENCE ON THE PLANTS – FIELD STUDY

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4.1 Introduction

A case study of Indian coal mine has been carried out for present work. The changes in nutrient content in the soil, as well as the plant leaves, have been determined in subsidence and non-subsidence area. Nutrients play a major role in the growth and development of plants. Plants take major nutrients from soil. Surface subsidence affects the nutrient content of the plants, thereby affecting their health. The imbalance of nutrient contents in subsided and un-subsided area can be measured through soil or directly from the plants. Care was taken in choosing mining area in such a way that the underground mining leads to subsidence at the surface and surface should have vegetation above the mining area as well as in the surroundings.

4.2 Study area and field investigation

The study site (Figure 4.1) has been selected in Anuppur district of Madhya Pradesh as it fulfilled the above requirement of the study. The area falls at the latitude range in between 23°11’00” N & 23°12’00” N and longitude in between 81°57’00” E and 81°58’30” E. The Kewai river passes nearby to the selected site and the area is mildly undulating with the overall slant towards river Kewai.

The area belongs to the humid subtropical climate zone; hence the climate here is mild and generally warm and temperate. The climate is similar to one in northern part of India. The year may be divided in four seasons, the hot summer (March to mid-June), rainy (mid-June to September), post-monsoon or transition period (October to November) and winter (December to February). There is less rainfall in winter compared to summer in this area. The normal annual rainfall of the area is 1235 mm. The district receives maximum rainfall during south-west monsoon period from June to September. About 80% to 90% of annual rainfall is received during monsoon season. The averages of maximum and minimum temperatures are 46ºC and 2.6ºC, respectively (MeitY 2021). During the south-west monsoon, the relative humidity generally exceeds 88% during the month of August. Relative humidity decreases during non-monsoon season. In summer season, relative humidity is less than 38%. May is the driest month of the year. The surface of mining area is covered with forest, agriculture and wasteland.

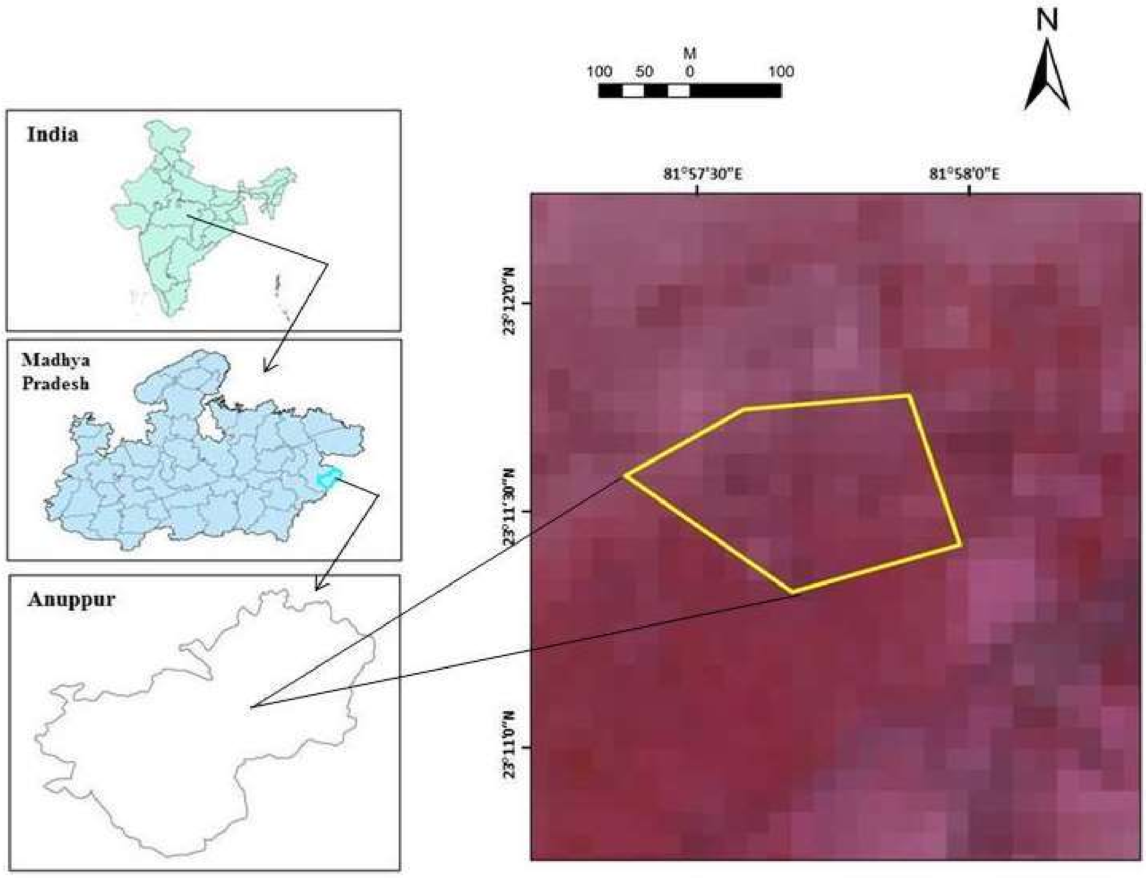


Figure 4.1 Location map of the study area

Vegetation of this region has been classified as Tropical Semi-Deciduous Forest (Champion and Seth 1968). The forest is dominated by the trees of Haldu, Tendu, Achar, Sal, Mahua, etc. The height of the dominant trees ranges from 6 m to 12 m. The ground vegetation of the region comprises a number of grasses like *Cymmbopogon, Cynodon, Hetropogon, Cyperus,* etc. and the herbaceous species like *Lantana camara, Solanum nigrum, Achyranthus aspera, Amaranthus spinosus,* etc. (MSME 2011). An underground mine has been selected for the present study. Board and pillar system of mining was being adopted in this mine. A panel of size 265m x 154m has been selected for detail study of this mine. The panel for this study has been selected in such a way that it is experiencing subsidence at the surface. The texture of the soil was mostly sandy clay loam. The pH of the soil extract varied from 6.15 to 6.20. The soil characteristics were slightly acidic in nature.

Figure 4.2 Tension cracks associated with subsidence basin observed in the study area

Field investigation of the study area has been carried out to study the impact of subsidence on plant health. The profile on the surface changes due to subsidence. It results into development of tensile and compressive strain zones on the surface. It is very difficult to identify the compressive and tensile strain zones in the field. Tensile strain results in cracks on the surface. These cracks are good markers for identifying tensile strain zones. Figure 4.2 shows the cracks on the surface due to mine subsidence in the subsidence area. Accordingly, three zones (undisturbed, tensile and compressive strain zones) were selected for sampling of soil and plant leaves.

4.3 IMPACT ON SOIL PHYSICOCHEMICAL PROPERTIES

Soil acts as a medium of growth, so it should have enough supply of nutrients to ensure proper growth of plants and harness a better forest ecosystem to balance the environmental conditions, wildlife conservations and economic values (Hopkins 2009). Surface subsidence due to underground coal mining changes the surface profile. This, in turn, changes the drainage pattern of the surface. Drainage pattern in rainy season leads to the accumulation of nutrients or deficiency as they are transported by water. Soil properties play a major role in growth and development of the plants. The soil properties may change or modify due to underground coal mine subsidence. The plants absorb nutrients from the soil. Therefore, any change in nutrients in the soil may affect the growth of plants.

NPK, i.e., **Nitrogen (N), Phosphorus (P) and Potassium (K),** are the most important elements for the proper growth and development of plants. Presence of nitrogen in soil is highly influenced by leaching, transformation and biological fixation (Nandy et al. 2007; Li et al. 2016). The decomposition process of litter influences the nitrogen concentration in soil, and its deficiency results into the infertility of soil (Ashman and Puri 2013). Phosphorus in soil exists as phosphate ion and is required in large amounts for the proper growth of plants (Gregor 2004). Potassium is also present in cationic form in soil (Ashman and Puri 2013).

Soil texture is an important soil characteristic that influences the rate of infiltration of water into soil. It determines the rate at which water drains through a saturated soil. Water moves more freely through sandy soils than it does through clayey soils. Soil texture influences how much water is available to the plants. Clay soils have a greater water holding capacity than sandy soils. Soils also differ in their susceptibility to erosion (erodibility) based on texture. A soil with a high percentage of silt and clay particles has a greater erodibility than a sandy soil under the same conditions. Sand, being the larger size of particles, feels gritty. Silt, being moderate in size, has a smooth or floury texture. Clay, being the smaller size of particles, feels sticky. The combined portions of sand, silt, and clay in a soil determine its physical property.

Therefore, it is observed from the above discussion that soil plays a very important role in plant's health, growth and development process. In this approach, the soil testing of surface soil of subsidence and non-subsidence area have been performed. The soil samples have been collected and testing has been achieved in laboratory to find out the effect of mine subsidence on soil pattern. The following physicochemical parameters of the soil have been measured: Available Nitrogen (AN), Available Phosphorous (AP), Available Potassium (AK), Sand percentage, Silt percentage, and Clay percentage.

4.3.1 Soil sampling

Three sets of samples were collected, one from undisturbed zone, second from tensile strain zone and third from the compressive strain zone. Figure 4.3 shows the schematic diagram of sample collecting zones. Plot sizes of 5m x 5m in size at each zone were selected for sampling. A schematic diagram of subsidence profile showing the sampling points has been presented in Figure 4.3. At each zone, sampling was carried out at four points (located on a systematic grid in a zig-zag manner covering the entire plots) by digging holes of 30 cm (~12 inch) diameters with the help of drill borer. Samples were kept in airtight plastic bags and carried back directly to the laboratory for further investigations.

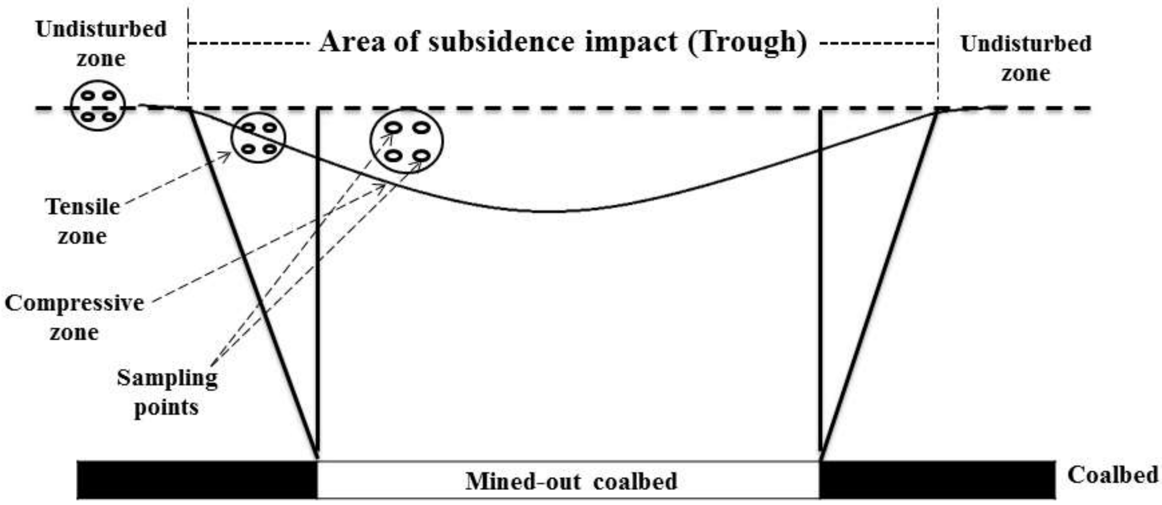


Figure 4.3 Schematic diagram of subsidence profile showing sampling points

4.3.2 Laboratory analysis

Soils were sieved through 2-mm mesh to remove litters, visible roots and other large plant materials after air-drying at room temperature for five days (Sofawi et al. 2017). The soil was then processed and homogenised for obtaining an average concentration of nutrients in the soil. Physicochemical analysis of the soil samples was performed in the soil chemistry lab of the Institute of Agricultural Sciences, BHU (Figures 4.4 & 4.5).

4.3.2.1 Soil physical (texture) and chemical analysis

Available nitrogen (AN) was measured by Kjeltec semi-auto nitrogen analyzer through alkaline potassium permanganate method (Subbiah and Asija 1956). Available phosphorous (AP) was analysed by Bray P_1 extract (0.03 N NH_4F in 0.025N HCl) (Bray and Kurtz 1945). Available potassium (AK) was evaluated by flame photometer (1 N NH_4OAc extract) method (Hanway and Heidel 1952). The analysis of sand, silt and clay was achieved by Bouyoucos hydrometer method (Bouyoucos 1962).

Figure 4.4 Sample collected from the field in bags

Figure 4.5 Laboratory Testing

4.3.3 Results and discussion

The soil samples collected from different zones, i.e., undisturbed, tensile and compressive strain zones were tested for the concentrations of available nitrogen, available phosphorus, available potassium, sand percentage, silt percentage and clay percentage. The results obtained from the laboratory analysis of the soil samples have been tabulated in the table 4.1. All the data shown in this table represent the average of the readings of the tested parameters. These results were used to compare the tested parameters of unaffected and subsidence zones. The subsidence zones have compressive and tensile strain zones. The effects of compressive and tensile strains of subsidence zones on soil parameters have been compared with the soil parameters of unaffected zones.

Table 4.1 Change in percentage of parameters in tensile and compressive zones against undisturbed zone

SN	Soil Characteristics	Amount in undisturbed zone	---------- Tensile zone ---------		----------Compressive zone--------	
			Amount	% Change	Amount	% Change
1.	AN (kg/ha)	296.32	285.96	-3.50	340.71	14.98
2.	AP (kg/ha)	17.64	15.65	-11.26	21.41	21.40
3.	AK (kg/ha)	213.18	205.55	-3.58	264.67	24.15
4.	% Sand	64.24	64.70	0.71	61.28	-4.60
5.	% Silt	8.99	8.06	-10.34	10.07	12.01
6.	% Clay	26.99	23.86	-11.60	30.75	13.95

4.3.3.1 Change in available nitrogen (AN), available phosphorus (AP) and available potassium (AK)

It has been observed from the table 4.1 that all measured nutrients have decreased in tensile strain zone and increased in compressive strain zone (as compared to the undisturbed zone). Available nitrogen, available phosphorus and available potassium have decreased in tensile strain zone by 3.5%, 11.26% and 3.58%, respectively while increased in compressive strain zone by 14.98%, 21.4% and 24.15%, respectively. The percentage change of the measured parameters in different zones can be seen in Figures 4.6a, 4.6b and 4.6c.

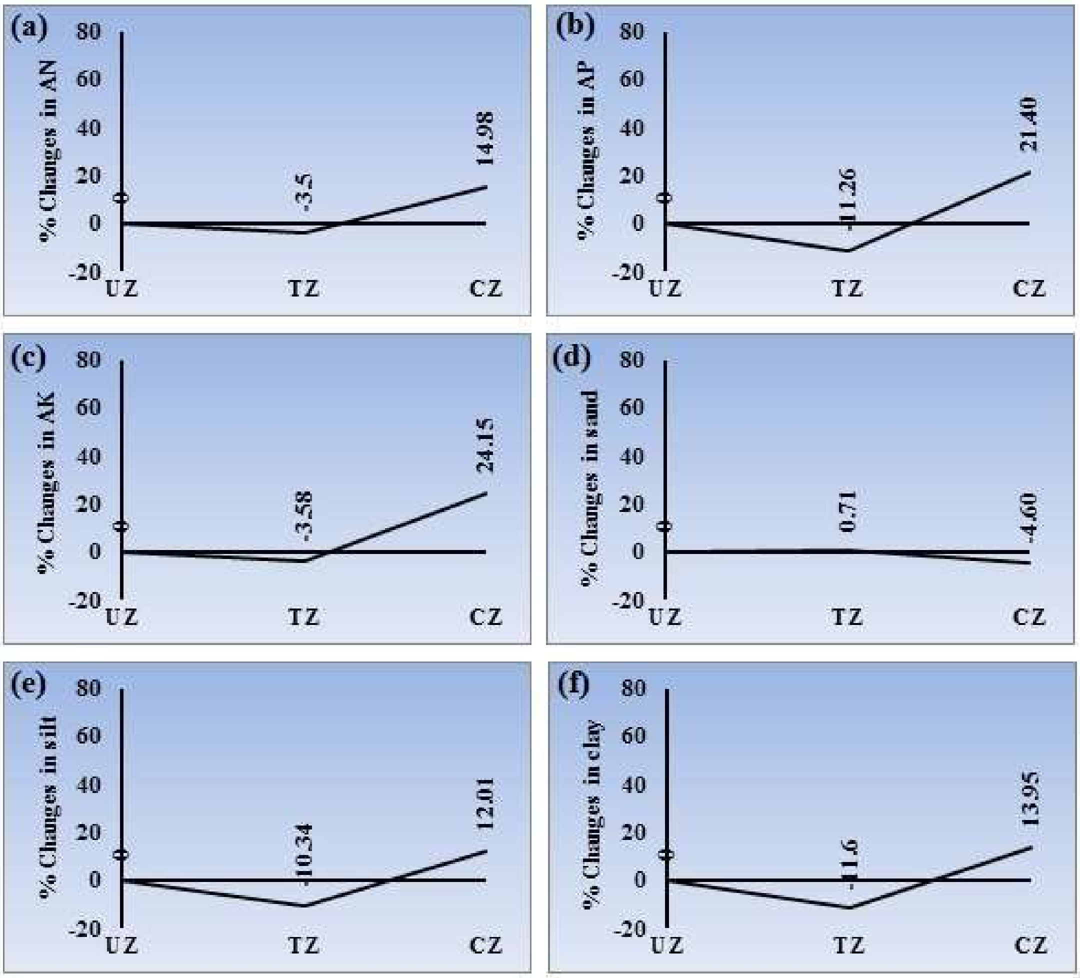


Figure 4.6 The percent change of AN, AP, AK, sand, silt and clay in tensile (TZ) and compressive zones (CZ) as compared to the undisturbed zone (UZ)

The reason for these changes could be attributed to the transportation behaviour of nutrients with the movement of water. At the point when soil turns out to be too much wet through precipitation, it arrives at a point where it can't hold any more water. This happens in light of the fact that the air spaces between soil particles become loaded up with water.

As these air spaces fill, gravity makes water descend through the soil profile. It can likewise pound or run off the surface of the soil. As water descends through the soil, nutrients are transported with it (Bradshaw and Chadwick 1980; Karol 2003).

Due to high strain, many cracks are formed in the tensile strain zone. The size of these cracks can range from small to very large. Due to the generation of cracks, there is a negative effect on the compactness of the soil here and the soil also becomes quite loose. The ability of these soils to hold the nutrients tightly is also greatly reduced and these soils are not able to bind the nutrients as well as they used to bind earlier. Nutrients are also transported along with the soil towards the compressive strain zone due to the effect of soil erosion during the rainy season. The amount of nutrients in tensile strain zone decreases while in compressive strain zone increases due to above phenomenon. It has also been observed that a small water lake has also been formed in subsidence trough in rainy season. It implies that there must have been movement of soil and nutrients along with the water towards the compressive strain zone.

The percentage of coarse-textured soil (sand) in compressive strain zone was found to be comparatively lower than the other zones. Coarse-textured soil shows a slow process of nutrient accumulation (Prescott et al. 2000) and are not a very good accumulator of nutrients as compared to the fine-textured soils (silt+clay). Hence, a higher percentage of fine-textured soil also leads to a higher accumulation of AN, AP and AK in compressive strain zone.

4.3.3.2 Texture analysis (sand, silt and clay)

The analysis results of the texture composition of the soils collected from different zones have been shown in Table 4.1. The variations of sand, silt and clay in tensile, compressive and undisturbed zones of the study area are represented in Figures 4.6d, 4.6e and 4.6f. It is clear from the Table 4.1 and Figure 4.6d that after subsidence, the percentage of coarse textured soil (sand) has been increased in tensile strain zone while decreased in compressive strain zone. On the contrary, percentage of fine textured soil (silt+clay) has been decreased in tensile strain zone and increased in compressive strain zone (Figures 4.6e and 4.6f). The sand increased by 0.71% in tensile strain zone while it decreased by 4.60% in compressive strain zone. Silt and clay decreased by 10.34% and 11.60%, respectively, in tensile strain zone and increased by 12.01% and 13.95%, respectively, in compressive strain zone.

The changes observed in the study area clearly indicate soil transport towards the depressed compressive strain zone. Soil particles that are coarser in nature, intended to have a less movement while soil particles that are fine (silt+clay) in nature, intended to have a greater movement towards the subsidence bottom with surface runoff. As a result, the movements of coarser-grained soils are limited to tensile strain zone, whereas fine-textured soil reaches up to the bottom (compressive strain zone) of the subsided land resulting into higher silt+clay percentages.

4.4 IMPACT ON NUTRIENT CONTENTS OF PLANTS

Nutrient concentration in the tissues of a plant, especially foliage tissue, is directly related to exchange processes between matter and energy, including photosynthesis, evapotranspiration and respiration (Marschner 1995). Consequently, evaluation of leaf nutrient concentrations is useful for understanding the health and growth of the plants.

Researchers have identified plant essential nutrients and grouped them according to the relative requirements of each that plants need. **Primary nutrients**, also known as

macronutrients, are those usually required in the largest amounts. They are Nitrogen (N), Phosphorus (P), and Potassium (K). **Secondary nutrients** are those usually needed in moderate amounts compared to the primary essential nutrients. The secondary nutrients are calcium (Ca), magnesium (Mg), and Sulphur (S). **Micro- or trace nutrients** are required in tiny amounts compared to primary or secondary nutrients. Micronutrients are Copper (Cu), Iron (Fe), Manganese (Mn), and Zinc (Zn). Each essential nutrient affects specific functions of plant growth and development (Epstein 1972; Peterson 1974; Marschner 1983; Bould 1975; Adams 1986; Bussler and Epstein 1972).

Nitrogen (N) is necessary to create amino acids, which in turn make proteins. These are necessary for the growth of leaves and stems. Nitrogen is needed in plant respiration and photosynthesis (Vitousek et al. 2002; Bruijn 2015). **Phosphorus (P)** is needed to help seeds germinate and for the growth of roots (Malhotra et al. 2018). This support of the root system is especially necessary for young plants and root vegetables such as carrots and beets (Heydari et al. 2019; Shen et al. 2003). Phosphorus is needed to make DNA (Deoxyribonucleic Acid), RNA (Ribonucleic Acid), phospholipids and ATP, or adenosine triphosphate, which carries energy to the plant cells and is needed for photosynthesis (Malhotra et al. 2018; Bieleski and Ferguson 1983; Dobrota 2004). DNA contains the plant's genetic code, and RNA carries instructions from the DNA from one part of the cell to another (Pearson 2006). Phospholipids are fats that help make up the cell membrane. They're made up of fatty acids, a glycerol unit, a polar molecule and a phosphate group (Wilson et al. 2019; Papahadjopoulos 1974). **Potassium (K)** is necessary for the creation of flowers and fruit. It also imparts disease resistance. It controls how water is taken up in the roots and how it is discharged through the leaves (Pandey and Mahiwal 2020; Wall 1939; Wall 1940).

Calcium (Ca) helps other nutrients to get into the plant and helps enzymic reactions. Calcium pectinate helps bond the plant's cell walls together (Gawkowska et al. 2018; Lara-Espinoza et al. 2018). **Magnesium (Mg)** is responsible for healthy leaves and chlorophyll, the green pigment that is important in photosynthesis (Farhat et al. 2016; Ye et al. 2019; Tang et al. 2012; Tränkner et al. 2016). It also helps to create ATP (Kleczkowski and Igamberdiev 2021; Cakmak and Yazici 2010; Guo et al. 2016) and, like calcium pectinate, helps glue the cell walls to each other (Favaro et al. 2008; Van 1991). **Sulphur (S)** is used by the plant to make amino acids (Abrol and Ahmad 2003; Dijkshoorn and Wijk 1967; Abdin et al. 2003; Scherer 2001).

Copper (Cu) is important in photosynthesis and the reaction of enzymes (Gong et al. 2019; Kebeish et al. 2014; Burzyński 2005; Yruela 2005). **Iron (Fe)** goes into cytochromes, which are necessary for plant transpiration (Hochmuth 2011; Lal 2018). It also helps the plant make chlorophyll (Spiller 1982). **Manganese (Mn)** helps form chlorophyll and enzymes (Twyman 1951). It helps make chloroplasts, the tiny bodies found only in the plant cell that make food and contain the molecules of chlorophyll. Manganese is important in plant respiration (Bottrill et al. 1970; Twyman 1951; Mukhopadhyay and Sharma 1991). **Zinc (Zn)** activates enzymes and allows the reading of the plant's genetic code (Frassinetti et al. 2006).

Therefore, nutrients are very important in the growth of the plants. The subsidence due to underground coal mine may affect the pattern of nutrients in the plants. The subsidence leads to the formation of large cracks. The roots of plants located above the mining area experience stress condition, as the subsidence takes place. Root of plants might be disturbed due to compressive or tensile stress and their growth might be affected. The root system gets damaged due to cracks and thus, the damaged roots affect the plant's growth.

The study of changes in nutrient concentrations in plant due to subsidence of underground coal mines has been carried out in the present work. Leaves of abundant plant species (*Shorea robusta* and *Lantana camara*) of the study area have been collected from tensile strain zone (TZ), compressive strain zone (CZ) and unaffected zone (UZ). The amounts of Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Manganese (Mn), Zinc (Zn), Iron (Fe) and Copper (Cu) in leaves have been collected from different zones. The nutrients in the leaves have been measured in the laboratory.

4.4.1 Leaf sampling

Young leaves of mature plants of *Shorea robusta* and *Lantana camara* (the abundant plant species of the study area) were collected from compressive strain zone (CZ), tensile strain zone (TZ), and undisturbed zone (UZ). Care was taken to sample at comparative phenological stages since it has been shown many times that nutrient contents in plants undergo seasonal variations (Körner 1989). Samples were thus taken at early flowering stages (mid-summer) when the vegetative development of plants usually reached a peak. Leaves were placed in clean, perforated plastic bags, kept in cold storage, and transported in an insulated container to the laboratory for further analysis.

4.4.2 Laboratory analysis

Samples were dried at 80°C, grounded, dried again, and cooled in a desiccator, then digested and subjected to ICP-MS testing (Inductively Coupled Plasma - Mass

Spectrometry, Figure 4.7) for elemental analysis (Pequerul et al. 1993) in subsidence affected and unaffected plants.

Figure 4.7 Laboratory analysis of the leaves

4.4.3 Results and discussion

The leaf samples of two types of plants, i.e., *Shorea robusta (ShR)* and *Lantana camara (LC)* collected from undisturbed, tensile and compressive zones have been tested for the concentrations of N, P, K, Ca, Mg, S, Mn, Zn, Fe and Cu. The results obtained from the laboratory analysis of the leaf samples *Shorea robusta and Lantana camara* have been shown in tables 4.2 and 4.3. All the data given in these tables represent the average of the readings of the above parameters. These results have been used to compare the effects of subsidence on nutrient concentration of plant leaves located in compressive and tensile strain zones in comparison to unaffected zone.

Table 4.2 Leaf nutrients of *Shorea robusta (ShR)* in subsided and unsubsided (or undisturbed) zones

		Undisturbed zone (UZ)	----------------------------Subsidence zone------------------------------			
			---------- Tensile zone ----------		----------Compressive zone--------	
SN	Nutrients (ShR)	Concentration	Concentration	% Change compared with UZ	Concentration	% Change compared with UZ
1	**N (mg/gm)**	9.1	9	-1.10	9.3	2.20
2	**P (mg/gm)**	2.06	1.9	-7.77	2.3	11.65
3	**K (mg/gm)**	4.26	4	-6.10	4.7	10.33
4	**Ca (mg/gm)**	7.38	6.52	-11.65	7.8	5.69
5	**Mg (mg/gm)**	13.5	13.4	-0.74	13.65	1.11
6	**S (mg/gm)**	4.15	3.8	-8.43	4.6	10.84
7	**Mn (mg/kg)**	6.71	6.6	-1.64	6.8	1.34
8	**Zn (mg/kg)**	1.56	1.52	-2.56	1.6	2.56
9	**Fe (mg/kg)**	2.8	2.64	-5.71	2.9	3.57
10	**Cu (mg/kg)**	2.28	2.19	-3.95	2.4	5.26

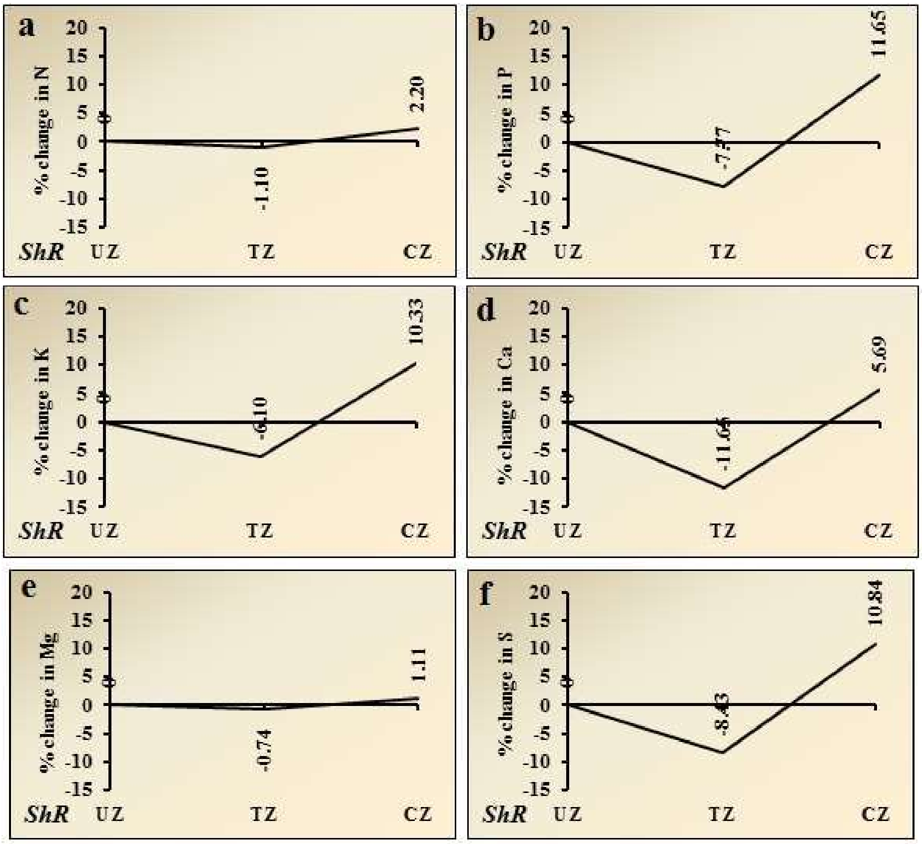
Table 4.3 Leaf nutrients of *Lantana camara (LC)* in subsided and unsubsided zones

		Undisturbed zone (UZ)	----------------------------Subsidence zone------------------------------			
			---------- Tensile zone ----------		----------Compressive zone--------	
SN	Nutrients (LC)	Concentration	Concentration	% Change compared with UZ	Concentration	% Change compared with UZ
1	**N (mg/gm)**	10.99	10.92	-0.64	11	0.09
2	**P (mg/gm)**	2.91	2.62	-9.97	3.12	7.22
3	**K (mg/gm)**	4.91	4.83	-1.63	4.98	1.43
4	**Ca (mg/gm)**	7.32	7.2	-1.64	7.5	2.46
5	**Mg (mg/gm)**	14.28	14.02	-1.82	14.47	1.33
6	**S (mg/gm)**	8.59	8.29	-3.49	8.78	2.21
7	**Mn (mg/kg)**	4.92	4.83	-1.83	5	1.63
8	**Zn (mg/kg)**	1.98	1.97	-0.51	2.1	6.06
9	**Fe (mg/kg)**	3	2.9	-3.33	3.2	6.67
10	**Cu (mg/kg)**	2.41	2.35	-2.49	2.5	3.73

4.4.3.1 Change in the leaf nutrients of *Shorea robusta (ShR) and Lantana camara (LC)* in tensile strain zone

Figures 4.8 and 4.9 show the leaf nutrients of *ShR* and *LC* located at tensile and compressive strain zones in terms of percentage change to undisturbed zone. These figures show that the amount of leaf nutrients in tensile strain zone have decreased as compared to the undisturbed zone.

The primary and secondary nutrients, i.e. N, P, K, Ca, Mg and S decreased in tensile strain zone by 1.1%, 7.77%, 6.1%, 11.65%, 0.74% and 8.43%, respectively in *ShR* while by 0.64%, 9.97%, 1.63%, 1.64%, 1.82% and 3.49%, respectively in *LC*. The micro or trace nutrients, i.e., Mn, Zn, Fe and Cu, decreased by 1.64%, 2.56%, 5.71% and 3.95%, respectively, in *ShR* while by 1.83%, 0.51%, 3.33% and 2.49%, respectively in *LC*. It can be observed from the above results that the horizontal tensile strain caused by underground extraction had negative effects on nutrient contents of the plants.



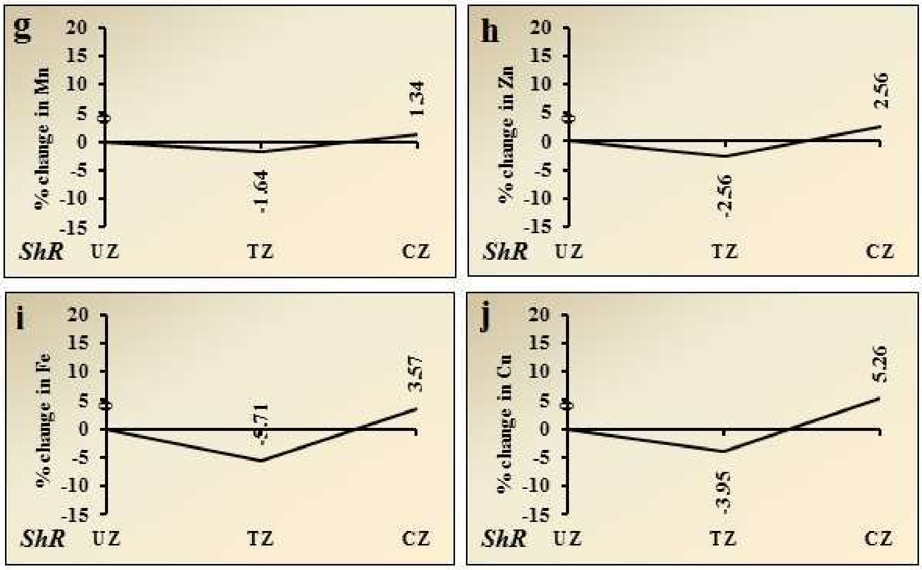
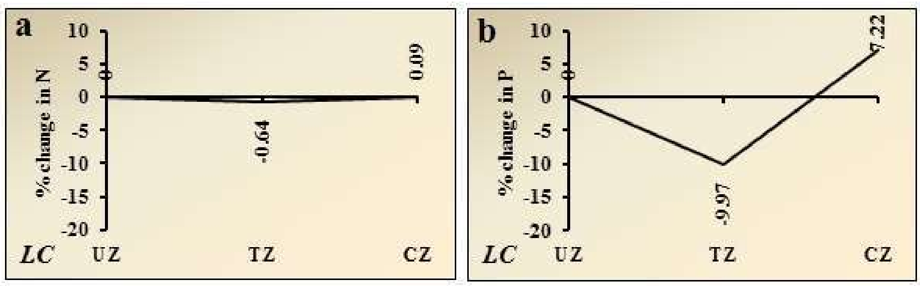


Figure 4.8 The percent changes of leaf nutrients of *Shorea robusta (ShR)* in tensile (TZ) and compressive strain zones (CZ) as compared to the undisturbed zone (UZ).

The impact of coal mining subsidence on leaf nutrients is mainly linked to the change in the soil growth environment (such as soil nutrients and soil texture composition) of the plants. The study of soil samples from the study area shows that the amount of soil nutrients available to plants in tensile strain zone decreases due to mining subsidence, which is reflected as comparatively lower amount of nutrients in the plant's leaves located in this zone.



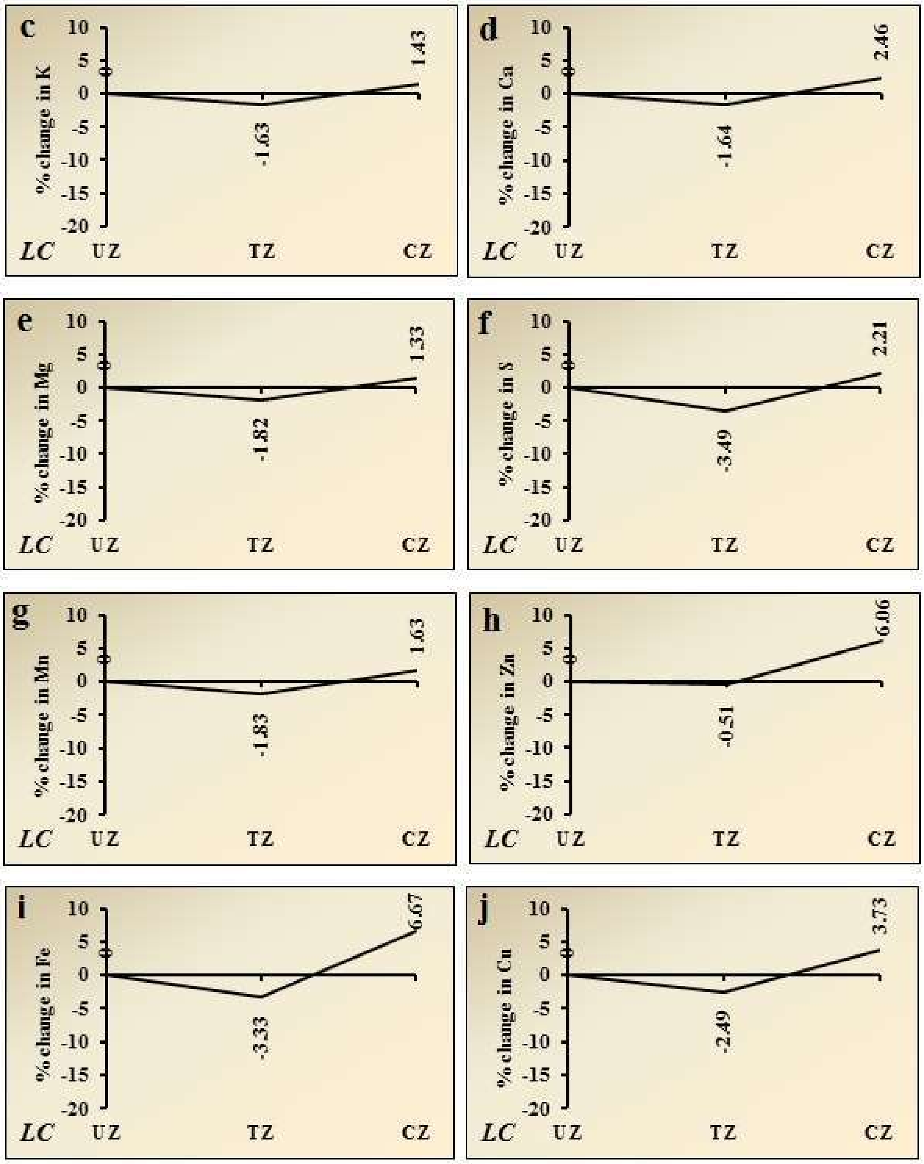


Figure 4.9 The percent change of leaf nutrients of *Lantana camara (LC)* in tensile (TZ) and compressive strain zones (CZ) as compared to the undisturbed zone (UZ).

A large number of surface cracks increase the evaporation in soil of tensile strain area. It accelerates the evaporation of groundwater along with a decrease in the movability of the soil nutrients. As the presence of cracks in tensile strain zone was prominent in the study area, this could be an important reason for the decrease in the nutrient supply of the plants located in tensile strain zone. This is comparable to the results of research by Zhang et al. (2017a) on the effects of surface cracks caused by coal mining, in which he concluded that surface cracks resulted in loss of water and nutrients and reduction in crop yield, which become more serious with larger cracks. The existence of the fissures modifies the process and direction of the surface runoff, which then infiltrates into the soil in the form of a preferential flow, modifying the distribution of nutrients in the soil (Qing-jun et al. 2009; Ma et al. 2014b; Guo et al. 2018) and ultimately the nutrients uptake by the plants.

4.4.3.2 Change in the leaf nutrients of *Shorea robusta (ShR) and Lantana camara (LC)* in compressive strain zone

It has been observed from the figures 4.8 and 4.9 that the amount of leaf nutrients of both the plants *ShR and LC* has increased in compressive strain zone as compared to the undisturbed zone. Primary and secondary nutrients i.e., N, P, K, Ca, Mg and S increased in compressive strain zone by 2.2%, 11.65%, 10.33%, 5.69%, 1.11% and 10.84%, respectively in *ShR* while by 0.09%, 7.22%, 1.43%, 2.46%, 1.33% and 2.21%, respectively in *LC*. Whereas the micronutrients, i.e., Mn, Zn, Fe and Cu, increased by 1.34%, 2.56%, 3.57% and 5.26%, respectively in *ShR* while by 1.63%, 6.06%, 6.67% and 3.73%, respectively in *LC*. It can be observed from the above results that the compressive strain zone caused by underground extraction had positive effects on nutrient contents of the two types of plants of this zone. In the crack region, despite a series of changes in soil nutrient composition and plant nutrient uptake process, plants at compressive strain zone could achieve greater amount of nutrients in their leaves compared to the undisturbed zone.

The concentrations of soil nutrients were higher in compressive strain zone (section 4.4.3.1). There is every likely hood that the leaves in compressive strain zone will have higher concentration of the nutrients. This phenomenon is observed in the study conducted on the leaves of the compressive strain zone.

4.5 Concluding remark

Field study has been carried out to study the impact of subsidence on the health of plants. A coal mining panel has been selected where the surface was experiencing subsidence and has plants on the surface. The focus of this study was to study the nutrients in the soil as well as in the leaves of the plants. Two plants, namely *Shorea robusta* and *Lantana camara* has been chosen as they were abundantly available on the surface. Three specific zones were selected for soil and leave sampling in the study area, i.e., tensile strain zone, compressive strain zone and unaffected zone.

Nutrients and texture analysis were carried out for the soil samples collected from abovementioned three zones. Similarly, leaves from *Shorea robusta* and *Lantana camara* were also collected from abovementioned three zones and nutrient contents of the leaves were analysed in the laboratory.

It has been observed that the subsidence affects the characteristics of the soil on the surface. The surface profile gets altered due to subsidence and the drainage pattern changes. Cracks etc., are also formed in tensile strain zone, whereas there is a compaction in compressive strain zone. The percentage of coarse textured soil (sand) increases in tensile strain zone while it decreases in compressive strain zone. The fine textured soil (silt+clay) decreases in tensile strain zone and increases in compressive strain zone. Available nitrogen, available phosphorus and available potassium have decreased in tensile strain zone while increased in compressive strain zone. Thus, the concentrations of leaf nutrients in tensile strain zone have decreased while the concentrations of leaf nutrients in compressive strain zone have increased as compared to the undisturbed zone in both the plants.

It could be concluded from the above results that the important nutrients are in deficiency in tensile strain zone and they are comparatively better in compressive strain zone. So it is likely that the health of the plants will get damaged in tensile strain zone and it will either remain unaffected or will slightly improve in compressive strain zone.

It is to be noted that the similar condition has also been observed in the previous chapter, where laboratory investigations were carried out on the impact of subsidence on the growth of the plants.