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# Dynamics of soil desurfacing due to brick kilns and suggestive management techniques

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**Abstract**
To suggest remedial measures and amelioration processes for the reclamation and improving the productivity and fertility of the desurfaced soils emerging due to brick kiln activity in national capital region (NCR) of Haryana (India). The investigation to assess desurfaced soils has been carried out in Rohtak and Jhajjar zones, integrating remote sensing obtained digitized data and ground truth verification in study area. Various processes of soil amelioration and reclamation of desurfaced soil have been suggested in the manuscript like use of organic matter (OM), Poultry manure, Animal waste, Press mud, Farm yard manure (FYM), Crop residues, Vermi-compost, Bio Char, Green manuring, Leguminous crops in crop rotation, Deep tillage, Gypsum use, Bio-fertilizers, Social forestry, Fishery ponds, Balance fertilization, Supplementary doses of extra 25-50 % doses of fertilizers and Micronutrients, and Soil replacement, etc.

**Keywords:** Remote sensing, Desurfacing, NCR

## 1. Introduction
Land is the basic natural resource that provides habitat and sustenance for living organisms, as well as being a major focus of economic activities. Degradation of land refers to loss of its potential production capability because of degradation of soil quality and its loss for effective use. In national capital region (NCR) of Haryana (India), the topsoil degrades due to human interventions. The functional capabilities of soil deteriorate from activities related to agriculture, forestry, and industry. On the other hand, urban sprawling and infrastructure development cause loss of available land resource.

Removal of the topsoil by any means has through research and historical evidence, been severally shown to have many deleterious effects on the productive capacity of the soil as well as on ecological wellbeing, [4]. Captioned the impact of soil erosion in their popular maxim the thin layer of soil covering the earth's surface represents the difference between survival and extinction for most terrestrial life. This degradation is mainly because of earth desurfacing. Earth desurfacing, we mean removal of topsoil (manually or mechanically) for other purposes like foundation for construction work, laying railway tracks and for making clay bricks. When the land degrades, its productivity declines abruptly, unless steps are taken to restore productivity and check further loss, [1]. Unprecedented increase in population and unwarranted human activities are mainly responsible for environmental degradation *via* fast urbanization and industrialization. Bricks, an essential basic material used frequently in construction, are a fundamental commodity for accomplishing various infrastructural projects for developing new urban areas. Its production near cities has become essential due to need-based market and carrying cost. The productive agricultural land is the best material for brick making because of its clay and silt content. The irony of the situation is that the soil, which could have provided a large amount of agriculture produce, in turn being used for raising man made cement mountains in the mega cities. Swelling urban population has necessitated vast lands for quarrying, to cater to the corresponding exaltation in demand for bricks and construction materials. Extensive areas quarried for clay and silt that is needed to mould the bricks. The kiln itself occupies approx. 0.8 hectares of land for establishment and additional 6-8 hectares for topsoil for molding bricks. The land change has a tilling impact on the quality and fertility status. In addition, quarrying degrades land often to such an extent that its restoration to a cultivable order is quite difficult. Degradation due to desurfacing has enormous impact on soil productivity.

Desurfacing impacts agriculture the most, by way of decreasing agriculture production drastically by reducing fertility levels of the soil. It decreases fertility status of the soil, and due to lack of essential nutrients, crops reported to be prone to many pests and diseases as well. To recover the production, farmers have been applying heavy doses of chemical fertilizers, which have other harmful consequences. However, this also destroys soil health by altering its composition and organic matter levels, exposing sub horizons, which are inherently poor in providing suitable environment to plant growth. The poor water transmission due to low hydraulic conductance of water, infiltration rate, compaction of soil, high bulk density, collectively responsible for creating degraded soil. It affects the sustainable development through the inter-relationship with important social problems such as poverty, poor health, and nutrition, lack of food security. Developing urbanization near mega city like Delhi, which needs more infrastructures, has increased the demand for basic material like bricks dramatically in recent past. There has been many fold increase in number of brick kilns in Haryana, particularly in national capital region (NCR).

While mapping the desurfaced soils for their management using remote sensing technique, the stereo data is highly useful in identification of different landforms, which have close relationship with the soils associated with them. The stereo data from panchromatic (PAN) cameras aboard SPOT/ IRS-1C/ Cartosat-I, enabled the delineation of physiographic units and soil maps derived there from in a better way. Management of natural resources particularly soil, is very essential for sustainable development of living beings on the land. The effect of ever increasing population pressure, urbanization and industrialization have put a great stress on our natural resources, resulting in decrease in net cultivable land area. There is an urgent need to study the impacts and formation of desurfaced soils in Haryana state, for preparing a composite and comprehensive planning strategy to combat unsustainable development and for their proper management. In present study, an attempt has been made to assess the characteristics and types of existing cultivable wastelands emerging because of brick kiln activities and to suggest fruitful possibilities of its reclamation and management for sustainable agriculture development. In order to fulfill the requirement of the objective, relevant data has been acquired from Haryana Space Application Centre (HARSAC-CCS-HAU campus)-Hisar and research work accomplished at this centre.

## 2. Objective

"To suggest remedial measures and amelioration processes for the reclamation and improving the fertility of the desurfaced soils emerging due to brick kiln activity"

## 3. Material and Methods

### 3.1 Study area and location:

The study area includes two zones, Rohtak and Jhajjar of Haryana state (India). Looking into the various agricultural problems like land degradation, lack of systematic information about soils of Rohtak and Jhajjar zones, it was considered important and urgent to perform systematic survey of these zones using Remote Sensing advance techniques to ascertain the magnitude and extent of the impact of various land degradation factors like soil desurfacing due to brick kiln activity. Fig. 1 depicts exact location of the study area chosen for present investigation.

Rohtak zone lies in 28° 23″ to 29° 6″ North latitude and 76° 13″to 76°58″East longitude in the national capital region (NCR) of Haryana state, situated 70 km North West from Delhi and

located 235 km from state capital, Chandigarh. It occupies total geographical land area of 1745 km$^2$ with greatest length and breadth is 62.5 Km and 44.0 km, respectively. It is in the elevation range of 222 m from the average sea level.

The Jhajjar zone lies in $29^o$ 21' 30" to $29^o$ 51' 30" to North Latitude, $76^o$ 16' 30" to $76^o$ 58' 45" East Longitude in the NCR of Haryana state.. Total geographical area of Jhajjar zone is 1834 km$^2$.3.2 Survey of India topographical sheets and details:

Survey of India (SOI): Scale 1: 25,000 Sheet number: 53C/8, 53C/12, 53C/4, 53D/o1, 53D/5, 53D/6, 53D/7, 53D/9, 53D/10, 53D/11, 53D/13, 53D/14, and 53D/15

### 3.3 Geomorphology and soil types:

The study area falls in eastern zone of Haryana (India), which covers around 49 % area of the state. This zone is also called wet zone. More than 70 % of the rainfall received during southwest monsoon. Normal rainy days are >30 per

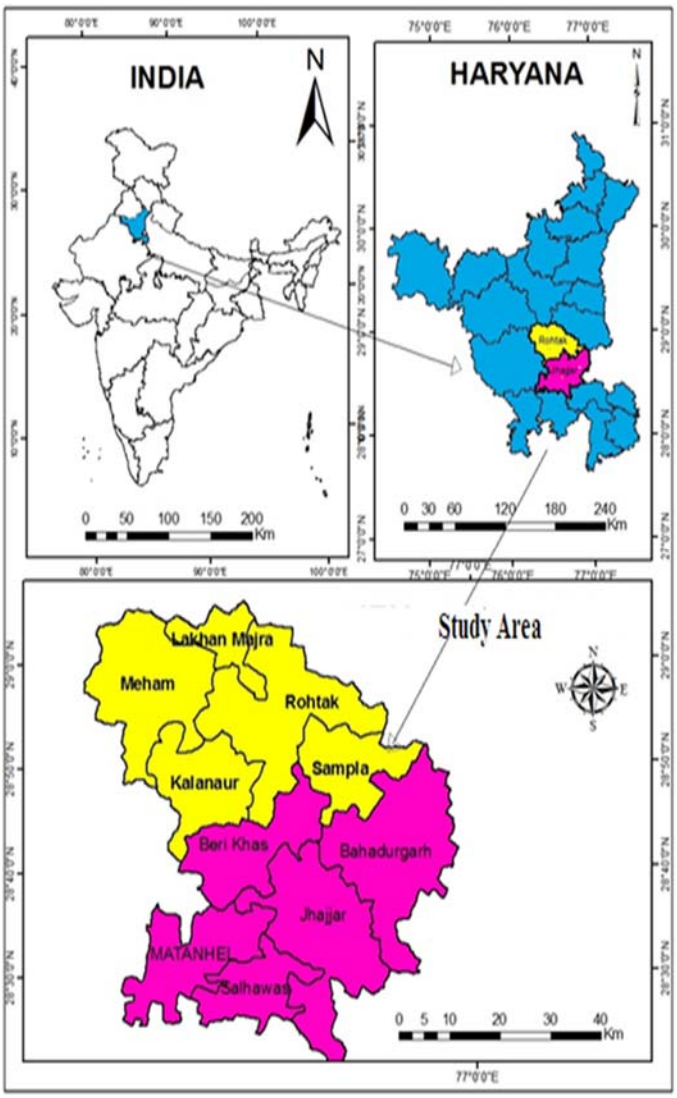


**Fig. 1** GPS location of study area in India and Haryana state map, [9]

Annum. Mostly the land of the study area is flat and plain except southwestern part of Jhajjar zone, which has sand dunes in this part. This is further manifested into additional three sub-units because of the Aeolian action in the Holocene period as (a) hummocky phase (fossils and dunes), (b) sandy plains of recent times (c) dotted lack extension along the central track surrounded by waterlogged areas. The soils of study area are mostly sandy-to-sandy loam.

### 3.4 Climate of the study area:

Hot in summer, highest day temperature ranging between 23$^{o}$C - 45$^{o}$C. Sub-tropical, semi-arid, continental mainly rains bring by southwest monsoon in the season July - August- September. Rains are scanty to normal. The climate classified as tropical steppe, semi-arid and hot which is mainly dry and hot with dry summer except monsoon months, *i.e*., July to September when moist air of oceanic origin penetrates into the land. Winters are also extremely cold and mostly dry where temperature falls to as low as 2 - 3$^{o}$C. The mean seasonal temperature during *kharif* and *Rabi* season are 29-31$^{o}$C and 16-18$^{o}$C with relative humidity of 70% and 55%, respectively.

### 3.5 Farm mechanization and agriculture practices in study area:

Farm mechanization is a very important tool for improving productivity of different crops, time saving, reducing drudgery, timely farm operations, resource conservation protection from natural calamities, (Fig. 2).
In the study area, timely sowing of wheat due to zero tillage seed cum fertilizer drills (Fig. 5) has improved the productivity of wheat in recent years, which is a remarkable achievement in wheat production. Rotavator (Fig. 3) is very useful to pulverize soil before planting paddy crop and helps in enhancing crop productivity significantly. Similarly, Jhajjar district has also developed similar facilities and continuously heading for technological developments in the field of agriculture after its bifurcation in 1997. There is further need to create awareness among farmers for proper use of farm machineries for higher efficiency, saving human and energy resources. Even this small history of evolution, Jhajjar district growth follows transitory upward trend of progress in the overall agriculture development. Thresher (Fig. 4) is more useful for small farmers, who cannot afford big implements like combine. This is also useful when farmers need dry husk to use it as dry fodder for animals. In case of combine threshing, farmers burn dry husk of wheat and rice to avoid delay of next crop. Although this practice has been banned by the government to check air pollution and save environment.
Seed cum fertilizer drill (Fig. 5) is extremely important because seed and fertilizer placed at appropriate depth in wet zone of soil, without any chance of losing moisture, which is very important for germinating seed. For the application of phosphatic fertilizers, seed drill is extremely important because phosphorus is immobile in soil and its placement below seed is essential. Seed drill is very useful for uniform distribution and applying exact amount of seed and fertilizer as well, which enhances productivity by 5-10 %.


### 3.6 Remote sensing data acquisition and satellite information use:

Data for the accomplishment of the objectives of present study is acquired from Haryana Space Application Center (HARSAC), Hisar (India)-125004

**1. Cartosat-I** carry two state-of-the-art panchromatic (PAN) cameras that take black and white stereoscopic images of the earth in the visible region of the electromagnetic spectrum. The swath covered by these high-resolution PAN cameras is 30 km and their spatial resolution is 2.5 meters.

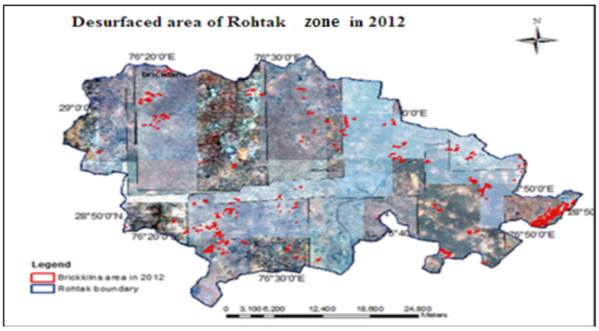


**Fig. 6** Desurfaced soil area in Rohtak zone in 2012 [9]

**2. Worldview-II** is a commercial earth observation satellite owned by Digital Globe (DG). Worldview-II provides commercially available panchromatic imagery of 0.46 m resolution, and eight-band multispectral imagery with 1.84 m (6 ft) resolution. It launched on October 8, 2009 to become Digital Globe's third satellite in orbit, joining Worldview-II,

### 3.7 Desurfaced soil formed in study area:

Remote sensing imagery digitized maps of desurfaced soil observed in Rohtak zone (Fig. 6) and Jhajjar zone (Fig. 7) in 2012

The desurfaced area due to brick kilns (Red spots in Fig. 6 and 7)) in study area

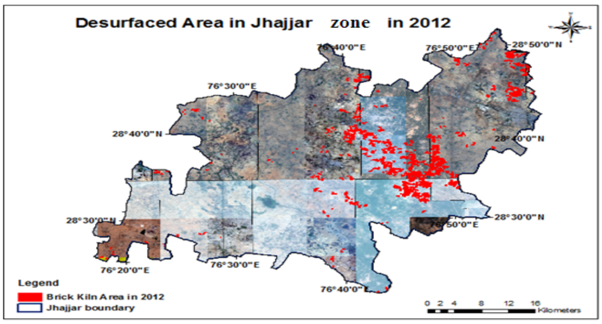


**Fig. 7** Desurfaced soil area in Jhajjar zone in 2012 [9]

was observed 3513.70 ha in 2007, increased to 4975.52 ha in 2012. The increase was of the order of 41.63 % in five years duration (Fig. 8).

## 4. Management of Desurfaced Soil

The removal of topsoil for urban uses mainly for brick making is growing rapidly due to the tremendous growth in urbanization and industrialization in many developing countries. Unfortunately, brick kilns are mostly situated on fertile agricultural land, as brick manufacturers need silty clay loam to silt clay soils with good drainage conditions.

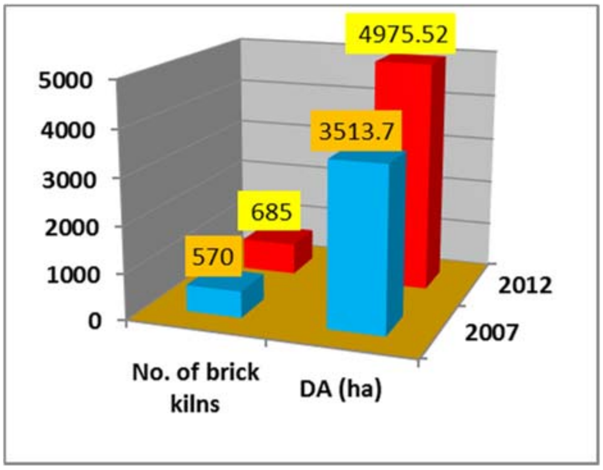


**Fig. 8** Desurfaced area in study area (Rohtak + Jhajjar zones) in 2007 and 2012 [9]

**DA=Desurfaced area, ha=hectare**

The urbanization and the requirement of brick manufacturers has resulted in change in land use pattern as the good agricultural land has been turned into agriculturally unproductive lands around several growing cities of the developing world. Population growth and high rates with the increasing price of raw materials for construction, especially clay bricks made entirely from exploiting our mud clay rich fertile topsoil for brick making and it will adversely affect the environment, thereby depleting a very precious natural resource, soil.

As degradation is a dynamic process, monitoring the indicators should be a continuous activity and evaluation of the results should be frequent. There is an urgent need for monitoring the desurfacing / degradation status monitoring based on scientific methods to arrest the activity of soil desurfacing and combat land degradation and improve soil quality index (SQI). The present study on soil desurfacing will serve as baseline scientific research work for any further monitoring and assessment of soil desurfacing in Rohtak and Jhajjar zones of Haryana state, especially major part of NCR.

In the year 2007 in Rohtak zone around 629.30 ha of desurfaced soil was observd, it increased by 41 % after five years, *i.e.* in 2012. Study also show that in Jhajjar zone, desurfaced soil area in the year 2007 was 2923.08 ha, further increased by 42 % after five years in 2012 to the tune of 4137.65 ha, which is a tremendous increase, [9].

Desurfacing is considered detrimental to plant growth and decreases productivity considerably due to loss of topsoil and exposes sub horizons, which is invariably poor in available nutrients, organic matter content, and biological activities, water holding capacity, hydraulic conductivity, and higher bulk density, [8] .

In this respect, some valuable suggestions for remedial measures for management, [14] and others are as follows:

**1. Use of organic matter** amendments like farmyard manure (FYM), animal waste, poultry manure, vermin - compost, press mud and crop residues, *etc.*, such materials will be helpful in rejuvenation process reviving biological activities in desurfaced soils. It will improve soil structure and fertility status of soil. It will also help in reducing bulk density and increasing water holding capacity and hydraulic conductivity of desurfaced soil.

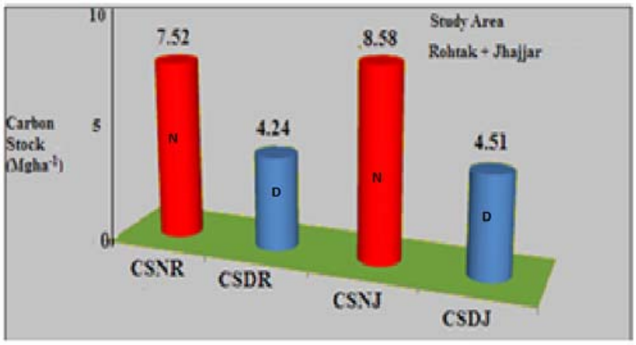


**Fig 9:** Carbon stock (Mg ha$^{-1}$) in normal and desurfaced soils

CSRN=Carbon stock, Normal soil, Rohtak, CSRD=Carbon stock, Desurfaced soil, Rohtak

CSJN=Carbon stock, Normal soil, Jhajjar, CSJD=Carbon stock, Desurfaced soil, Jhajjar

Carbon Stock (Mg ha$^{-1}$) = O.C. (%) X B.D. (Mgm$^{-3}$) X Soil Depth (cm)

According to Fig. 9 desurfacing of soil has caused huge loss to organic matter stock of the soil (>40 %), which is a natural reservoir of plant nutrients. Preservation of this precious reservoir is utmost important from soil productivity and fertility point of view.

Crop residues (above and belowground) not only protect land from the ravages of wind and water erosion but also add organic matter to depleted soil and also supply several essential plant nutrients that are assimilated during crop production, [13]. Desurfaced soils of Rohtak and Jhajjar zones are highly depleted in their organic carbon stock capacity as depicted in following figure.

**2. Using Bio char as soil amendment for sustainable agriculture:** Bio char is a charred carbon-enriched material intended to be used as a soil amendment to sequester carbon and enhance soil quality. Sustainable bio char produced from waste biomass using modern thermo chemical technologies. Addition of sustainable bio char to soil has many environmental and agricultural benefits, including waste reduction, energy production, carbon sequestration, water resource protection, and soil structure improvement. Therefore, the use of sustainable bio char as a soil amendment is an innovative and highly promising practice for sustainable agriculture, [17].

Bio char is the carbon-rich product obtained by heating biomass in a closed system under limited supply of oxygen. Currently, there are several thermo chemical technologies such as pyrolysis, gasification, and hydrothermal conversion to produce bio char. Pyrolysis involves the heating of organic materials in the absence of oxygen to yield a series of bio products: bio char, bio-oil, and syngas. Pyrolysis is a simple and inexpensive process, used to produce charcoal for thousands of years.

When used as a soil amendment, bio char has been reported to boost soil fertility and improve soil quality by raising soil pH, increasing moisture holding capacity, attracting fungi that are more beneficial and microbes, improving cation exchange capacity (CEC), and retaining nutrients in soil. Another major benefit associated with the use of bio char as a soil amendment is its ability to sequester carbon from the atmosphere-biosphere pool and transfer it to soil. Bio char may persist in soil for millennia because it is very resistant to microbial decomposition and mineralization. This particular characteristic of bio char depends strongly on its properties, which affected in turn by the pyrolysis conditions and the type of feedstock used in its production. Previous studies indicate that a bio energy strategy that includes the use of bio char in soil not only leads to a net sequestration of $CO_2$, but also may decrease emissions of other more potent greenhouse gases such as $N_2O$ and $CH_4$, [16].

Similar to activated carbon, bio char can serve as a sorbent in some respects. Bio char usually has greater sorption ability than natural soil organic matter due to its greater surface area, negative surface charge, and charge density, [7]. Bio char can not only efficiently remove many cationic chemicals including a variety of metal ions, but also sorbs anionic nutrients such as phosphate ions, though the removal mechanism for this process is not fully understood, [6]. Thus, the addition of bio char to soil offers a potential environmental benefit by preventing the loss of nutrients and thereby protecting water resources.

Sustainable agriculture is a way of raising food that is healthy for consumers and animals without causing damage to ecosystem health. Low nutrient content and accelerated mineralization of soil organic matter (SOM) are the two major constraints currently encountered in sustainable agriculture, [11]. Nutrients are retained in soil and remain available to crops mainly by adsorption to minerals and soil organic matter. Usually, the addition of organic matter such as compost and manure into soil can help retain nutrients. Bio char is considered much more effective than other organic matter in retaining and making nutrients available to plants. Its surface area and complex pore structure are hospitable to bacteria and fungi that plants need to absorb nutrients from the soil. Moreover, bio char is a more stable nutrient source than compost and manure, [2].

The modality of bio char in its ability to act as an effective soil amendment is similar to the traditional *slash-and-burn* fertilization method, where farmers remove the vegetation and release a pulse of nutrients to fertilize the soil. However, the *slash-and-burn* practice has an unfavourable environmental reputation because it is associated with deforestation and air pollution. In contrast, bio char production under a controlled system may provide a higher yield and have fewer detrimental effects on the environment. These characteristics make bio char an exceptional soil amendment for use in sustainable agriculture, [6], [18].

**3. Green manuring:** Green manuring by growing leguminous crops like dhaincha, berseem (*Trifolium alexandrinum*), which will help in reviving fertility of depleted soil by way of enhancing nitrogen fixing process.

**4. Use of biofertilizers:** Use of azotobacter for cereal crops and rhyzobium culture for leguminous crops (rhizobium fixes atmospheric N in the nodules of roots of the plant) will be very useful as amelioration amendment. They help in fixing atmospheric nitrogen in the soil and help in increasing biomass of soil.

**5. Deep tillage:** Deep tillage by using specific implements, like disk plough, to break the compact hard pan underneath in sub horizon is very effective. The roots of plants facilitated to explore more area for nutrients and moisture extraction. The bulk density, decreases and hydraulic conductivity and water holding capacity of soil increases due to deep tillage application. Deep tillage and use of gypsum helped to increase protein content of mustard, [3].

**6. Use of single superphosphate (SSP):** Use of single superphosphate as phosphatic fertilizer in place of DAP (Di-Ammonium Phosphate) will be more useful because it provides 12 % sulphur and calcium in addition to phosphorus. Sulphur will help in moderating pH of the degraded soil, improve availability of micronutrients, and very useful for oil seed crops (*Brassica sp*.), which require sulphur as constituent of sulphur containing amino acids like cystine, cystin, and methionine. Calcium helps in improving structure of degraded soil. Sulphur helped to increase oil and protein content of mustard, [12].

**7. Additional 25-50 percent fertilizers and balanced fertilization:** Additional 25-50 percent fertilizers of nitrogen, phosphorus, and potassium recommended for such soils to compensate lost nutrients and a balanced fertilization is essential considering all macro and micro essential plant nutrients. In addition, enhanced good quality water input than normal soil, will be useful.

**8. Micronutients:** Micronutrients like Zn, Fe, Cu and Mn recommended for such depleted soils.

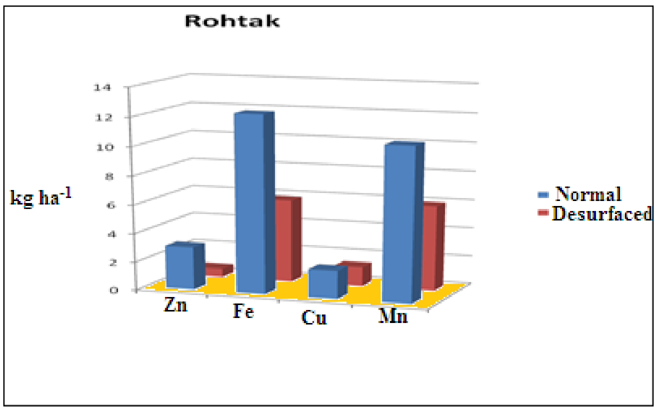


**Fig. 10** Micronutrient status of normal and desurfaced soils of Rohtak zone

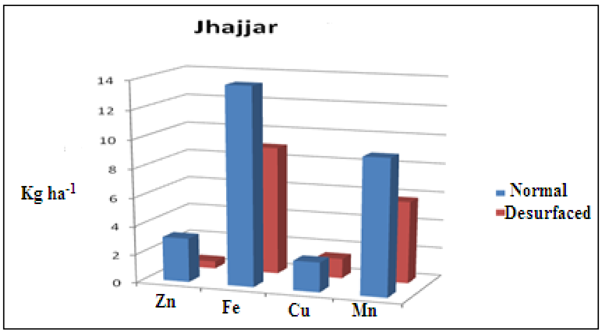


**Fig. 11** Micronutrient status of normal and desurfaced soils of Jhajjar zone

Percent decline of Zn (78.4 %), F**e** (39.34 %), Cu (31.74 %) and Mn (55.21 %) content, respectively, due to desurfacing in Rohtak district. There is drastic decline in micronutrients content in desurfaced soils of Rohtak district as is evident (Fig. 10). Micronutrients being essential elements for normal plant growth, their adequate levels in soil need to be maintained, otherwise productivity will suffer enormously.

Percent decline of Zn (80.40 %), Fe (60.02 %), Cu (54.78 %), Mn (47.26 %) content, respectively, in desurfaced soil of Jhajjar District. There is drastic decline in micronutrients content in desurfaced soils of Jhajjar distric (Fig. 11). Additional doses of micronutrients become essential in such prevailing situations where soil is extremely depleted due to desurfacing process.

**9. Use of gypsum as soil amendment for reclamation:** Use of gypsum as soil amendment also recommended under specific conditions like alkalinity problem, Areas in Jhajjar district where alkalinity problem is high due to indiscriminate use of sub soil saline water for manufacturing bricks. Gypsum- ($CaSO_4$) + ($MgSO_4$) is a rich source of calcium and sulphur which will be helpful in improving pH of the soil if contains high levels of Na. Gypsum will be helpful only in Sodic water and alkaline soil treatment. Soil analysis before going for finalizing the treatment is prerequisite and essential. Gypsum helps to increase efficiency of oilseed crops, [15].

**10. Integrated use of fertilizers, farmyard manure, green manure and vermi-compost** will be of great help in retrieval and ameliorating process to rejuvenate lost soil health and fertility and productivity. [19] also recommended integrated use of deep tillage, organic manure and green manure cropping and growing of trees along with enhanced doses of fertilizer for rapid restoration of seriously degraded soils at abandoned brick production sites in China. Trees are well adapted to gathering nutrients from deep in the soil profile, where much of the nutrient release from parent material takes place, and trees can act as nutrient pumps, taking up nutrients that occur deep in the profile because of weathering, and depositing them at the soil surface as litter that will decompose and release the nutrients.

**11. Alternative uses of desurfaced soils for social forestry:** also may grow leguminous trees, which have nitrogen fixing capacity, solid waste disposal sites, fishery, or farm pond needs explored for better soil amendment practice for desurfaced soils. Soil enriched by addition of trees foliations, waste decomposition in the form of humus, sufficient availability of good quality water from pond for soil reclamation purposes.

**12. Soil Replacement Process:** This process is also possible where land is undulated and availability of surface soil is abundant like sand dunes in Jhajjar district. If the process is cost effective, it is quite beneficial after enriching sand dune soil with organic matter.

## Conclusion

Desurfacing is detrimental to plant growth and decreases productivity considerably due to loss of topsoil and exposes sub horizons, which is invariably poor in available nutrients, organic matter content, and biological activities, water holding capacity, hydraulic conductivity, and higher bulk density. Various amelioration processes are beneficial for the reclamation of degraded soils.

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