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Restoration of Degraded Land Can Be a Key Pathway to Achieve Food Security in India

Dr Kalpana Kumari

Associate Professor, Department of Botany, Kalindi College University of Delhi, New Delhi, India

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ABSTRACT

Food security is a flexible concept and it refers to the food availability and one's access to it. A household is treated as invulnerable when its occupants do not live in hunger or fear of starvation. Food security assessment is divided into the self-sufficiency rate (S) and external dependency rate as this divides the largest set of risk factors. Although countries may desire a high self-sufficiency rate to avoid transport risks, this may be difficult to achieve especially for wealthy countries, generally due to higher regional production costs. The three aspects of food security are availability of food, access to food, and use of food. Food availability means having available sufficient quantities of food on a consistent basis. Access to food is having sufficient resources, to get foods for a nutritious diet. Food use is the proper use depending upon the knowledge of basic nutrition and care, with sufficient water and sanitation. A fourth facet is added by FAO to the stability of the first three aspects of food security over time.

Land degradation and desertification are serious problems in achieving food security. A large population in India still lies below the poverty line and is unable to have sufficient food because of unemployment and the degradation of land. People in developing countries are not concerned about their future meals. They ignore future food productivity, which leads to unsustainable natural resource management practices. The cost of food production is rising every year. Land deterioration occurred in the developing regions due to overgrazing, deforestation, land clearing, increased soil salinity, water logging, etc. Restoration of degraded land is a major concern in India. Rapid urbanization is also a major concern which causes decrease in the area of available land for cultivation in rural areas.

Key Words: Land degradation, Desertification, Food Security, Desertification, Agroforestry, Mycorrhizae, Microbes

INTRODUCTION

In 1983, FAO explained its concept of food security to include both physical and economic access to food supply: "ensuring that all people at all times have access to the basic food' (Shelke and Ahmed, 2015). The world's population is increasing and it may reach 9 billion by 2050. Hence, to meet the demand of increasing population, agricultural production will have to increase by 70%. India's population is growing by nearly 1.8% annually and it passed one billion in 1999. In the past 50 years India's population has risen by 650 million and could rise to 1.5 billion in the next century (Anonymous, 1991, 1998). Climate change adds a new dimension to this challenge as it is an important factor affecting the food system and contributing to rising food prices. Currently, 13 percent of the world's population is undernourished (Sharma et al., 2015).

Out of nearly 167.5 million sq. kms of total available land surface distributed among five continents and over 180 countries, only 18.25 million sq. kms of land are used for growing food. Large tracts of lands must be set aside as grasslands and pastures which must be maintained to grow food for animals. Some land is needed to grow fruits and vegetables and other cash crops. About 44.1 million sq. km stand forests with 40% or more of canopy cover (Asthana et al. 2012).

About 105.2 million sq. km of land comprise barren wasteland. Large tracts of land are occupied either by hilly terrains, barren deserts, or else are covered with ice where food cannot be grown. Bringing barren wasteland under cultivation is virtually impossible or extremely difficult. Forests cannot be converted into cropland because it is important to maintain global ecological balance and as storehouses of biodiversity. Most of our cities and industries are on the most productive land and cannot convert into cropland (Asthana et al. 2012).

Cereal was produced globally in 590 million hectares in 1950. It rose 720 million hectares by the year 1975-1976. However, there has been a decline of about eight million hectares in the last thirty years. We have probably reached the end. If we closely examine the data we shall find that much of this increment in the global area devoted to cultivation of cereals has come from an extension of our crop field over marginal soils - soils on hill slopes or water stressed areas which are not suitable for conventional agriculture. We have cleared hill slopes; carved steps cultivate cereals and other edibles. We have dammed rivers, dug canals to carry water to our water starved field. Cultivation on marginal soils requires more skilful management. Carrying capacity of these soils is often poor and has to be supplemented with an ever rising fertilizer and energy inputs to get higher yields, which is essential for soil health (Asthana et al. 2012).

To provide food to the rising global population, we shall have to grow more and more food from the existing croplands only (Hrabovsky, 1991). There are some regions of the world which are gifted with large tracts of productive land. South Asian countries have the highest proportion of richest and the most fertile land in the world (Asthana et al. 2012).

DEGRADATION OF LAND:

Degradation of land refers to the deterioration in the biological productivity of land because of human activities (Xie et al., 2020). Approximately 40% of the world's agricultural land is seriously degraded. In India, if current trends of degradation of soil continue, the continent cannot feed its whole population by 2025 (Sharma et al., 2015). The basic reasons for the degradation of land and fertile soils are the extensive clearing of the cover of vegetation, which protects the soil underneath. Extensive modification of land surface, construction activities, mining and processing operation etc. also contribute substantially to degradation of land. The plant cover over the surface of the soil exercises a strong control on the microclimate within the soil. Once the plant cover is removed, the soil is exposed to solar radiations and the battering action of wind and rains. The degradation of land is accelerated by pollution of the soil, which adversely affects the life of the soil. Every year we have to use more and more energy and add an ever rising quantity of fertilizers to maintain productivity (Asthana et al. 2012).

TABLE1: Statistics of degraded land/wastelands of India (M ha).

Degradation type	Arable land	Open forest	Data source
	(M ha)	(<40% canopy) (M ha)	
Water erosion (>10 Mg ha-1 year-1)	73.27	9.30	Soil loss map of India-IISWC, Dehradun
Wind erosion (Aeolian)	12.40	_	Wind erosion map of India CAZRI, Jodhpur (Aeolian)
Sub total	85.67	9.30	
Chemical degradation			
Exclusively salt-affected	5.44	_	Salt-affected soils Soils of India, CSSRI, Karnal; NBSS&LUP, Nagpur; NRSA, Hyderabad and others
Salt-affected and water eroded soils	1.20	0.10	
Exclusively acidic soil (pH<5.5)	5.09	_	Acid Soils of India, CSSRI, Karnal; NBSS&LUP, Nagpur
Acidic (pH<5.5) and water-eroded soil	5.72	7.13	
Sub total	17.45	7.23	
Physical degradation			
Mining and industrial waste	0.19		Wasteland Map of India-NRSA, Hyderabad
Waterlogging (permanent surface inundation)	0.88		
Sub total	1.07		
Total	104.19	16.53	
Grand total (Arable land open forest)	120.72		

Source: (Jinger et al. 2023).

Land degradation may be categorized into follows type:

Soil Erosion:

Among the salts, bicarbonates (HCO_3) and carbonates (CO_3) predominate which are deposited in the shape of *kankar*. In some places carbonates and bicarbonates of Sodium (Na_2CO_3 & $NaHCO_3$) along with a little amount of Sodium chloride ($NaCl$) and Sodium sulphate (Na_2SO_4) are present in higher quantities. Where subsurface drainage is proper these salts are usually washed away in the underground water table. However in localities where subsurface layers of hard impervious material persist, the dissolved salts accumulate. As the land dries up, capillary action brings up salts and colloidal material to the surface from deeper layers of the soil. The soil turns saline or alkaline and its fertility is severely hampered. These waters are in fact dilute salt solutions. Plants take up what they require. Where drainage is inadequate the residual salt content accumulates in the soil and in the long run causes problems of salinity and alkalinity. Because all Na+ and K+ and many Ca2+ and Mg2+ salts of chloride, sulphide, and carbonate are readily soluble, it is this set of ions that contributes most to soil salinity. At higher concentrations, the salts create a toxicity hazard (Asthana, et al. 2012).

Erosion of soil is displacement of soil, sediments, rock and other particulate material caused by air currents, flowing waters, movement of ice or subsidence of land under the influence of gravity. Erosion is a natural process, but in many places, it is increased because of improper use of land, which includes removal of the cover of vegetation, overgrazing, and unmanaged construction activity, etc. The soil loses its ability to soak up rainwater and shear strength because of the decrease of the cover of vegetation. The roots of trees, shrubs and grasses bind the soil particles together and provide it strength, while organic matter binds the soil particles in the soil crumb structure. Their disappearance loosens the top soil and makes it vulnerable to erosion. In water stressed regions, winds sweep away the sheet of finer surface particles and deposit them as sand dunes elsewhere (Sheet erosion) (Asthana et al. 2012).

Alkalinisation and Salinization:

Excessive accumulation of salts has affected 770.000 sq kms of global arable land area in the past. Worldwide, we are losing about 16,000 sq. kms of world's irrigated farmland every year because of alkalinisation and salinization (Ghassemi et al.1995). It is the over irrigated but poorly drained crop fields which have mostly suffered from the scourge of alkalinisation and salinization. About 1.12 million hectares and 0.52 million hectares of rich and fertile farmland in Uttar Pradesh and Punjab, respectively, suffer from a heavy accumulation of alkali and salts and have at their productivity. In India, alkalinisation or salinization or both have damaged about 8.2 million hectares of fertile cropland (Asthana et al., 2012).

Water Logging:

Water logging is a problem created by the rise of the underground water table very close to the ground surface. The water rises to the zone of roots of the plants, pushing out the air present in the interstitial spaces between the soils particles. This disturbs all processes within plant roots and the soil which needs oxygen. The fertility of land declines considerably. Excessive libration of water from the surface because of prolonged rain, seepage from canal systems and impoundments and influx of water through over irrigation is usually responsible for the development of water-logged conditions (Asthana et al. 2012).

In India, about 12.7 million hectares of precious agricultural land were reported to be waterlogged by 1992 (Abrol, 1994). The main area of the Sharda Sahayak project (UP) has waterlogged almost 78 thousand hectares of productive land. Irrigation projects on Chambal (Madhya Pradesh and Rajasthan) Gandak (Bihar and Uttar Pradesh) have wasted about 98.7 and 211.0 thousand hectares of productive land to water logging. Indira Gandhi canal in the north western Rajasthan has brought about extensive water logging of dry land. (Asthana et al.2012).

There are many reports of water logging associated with construction of large dams, reservoirs and the canals built to carry water to dry regions of the world. Water-logged soils have hard impermeable strata underneath which prevent downward or lateral infiltration of water. Water accumulates in the surface layers and saturates the soil because of the absence of proper underground drainage. The soils can support cultivation of coarse cereals, many of which can grow under dry and rough conditions. The soils cannot support the usual crops and the productivity declines dramatically. As these soils dry up under the scorching heat of the day during summers, the dissolved salts are brought up and deposited in the top layers while water evaporates (Asthana et al. 2012).

Soil Pollution:
Major soil contaminations result from pollutants adhering to the soil particle surface or lodging in the spaces in between the particles of the soil. The accumulation of pollutants in the soil depends on several factors. Some toxic materials may literally drain through soils such as sand and gravel and move under the influence of gravity to deeper layers. Soil contaminants have harmful effects on the soil systems. Because of the presence of many harmful chemicals, sudden changes in soil chemistry may arise, which brings changes in the metabolism of micro biota within the soil. Many microbes useful to soil may disappear altogether. In many cases, contaminants alter the plant metabolism, which shows up as reduced crop yields. The adverse effects on soil life disturb the soil texture, making it prone to soil erosion. Organisms living in the soil may absorb, accumulate and bio magnify the contaminants. Edibles produced on the contaminated land often possess higher concentration of the toxic materials and could be unfit for human consumption. Soil pollution, therefore, degrades a significant proportion of land area every year. Harmful substances accumulate in crops and via the food chain and food web bio magnify into a living being, where they can cause a variety of illnesses. Soil pollution also damages ecosystems and ultimately threatens their safety (Sunderesan, 1991).

Desertification:
Desertification is the degradation of land primarily caused by human activities and climatic variations. It involves the depletion of vegetation and soils and usually stems from the demands of increased populations that settle on the land in order to grow crops and graze animals (Asthana et al. 2012).
The desert could be developed at any place where the soil has been so mistreated by humans that it has become useless for growing crops. Desertification is because of cutting down forests and trees, over cultivation of the soil and overgrazing. When soils are poorly managed, they store less water and produce less grain, even when there is enough rainfall. The Sahara Desert is expanding southwards at the alarming rate of about 5-10 kms per year. 6 thousand hectares of agricultural land are irretrievable every year and turning into virtual deserts. According to reports, nearly 35% of the earth's land surface is threatened by prospects of desertification which could affect the livelihoods of about 850 million people (Asthana et al. 2012).

RESTORATION OF DEGRADED LAND:
The various methods for restoration of degraded land are as follows:

Organic Fertilizers:
India has a vast potential of organic waste resources, which include animal dung, animal urine, bone meals, slaughterhouse wastes, crop residues, oil cakes, urban garbage, sewage (sullage), effluent, etc. Many of these organic wastes remain unutilized, leaving scope for development of organic manures.

Table 2: Production and use of organic wastes (per day) in India

Source of organic waste	Production	Usage
Urban waste	15.0 m.t.	6.7 m.t.
Rural waste	650.0 m.t.	250.0 m.t.
Sewage (sullage) effluent	8 m. gallons	2.5 m.gallons

Source: (Gupta 2015-2016)

Agroforestry:
Agroforestry is a term used when woody perennials (trees, shrubs, palms, bamboo, etc.) are cultivated on the same land. The various components of agroforestry systems must interplay with each other ecologically and economically. Agroforestry provides a practical way to prevent hazards brought on by weather anomalies, manage soil erosion, and guarantee long-term sustainable output (Lundgren and Raintree, 1982).

Micropropagation:
The forests account for 29-34% of the land area on earth, on a world-wide basis, and for 19.52% (62.20 million ha) of the land area in India, where only 10.88% (35.79 million ha) is covered by closed Forests. While on the one hand, forests are a source of goods and services (including firewood, fodder pulp, and fibre industries), they also maintain pneumatic stability and conserve water and soil. Today, there is a gap between the supply and demand of forest-based materials, and the forests are being cleared, leading to degeneration of the environment. It has been proved that degraded lands can be effectively used and restored by planting forests using trees of wide adaptability and high productivity. In this manner, high yield of biomass and other plant products may be obtained from the degraded lands. For this purpose, it is recommended that micropropagation of superior genetic stocks rather than seeds of uncertain genetic quality should be used. In tropical and subtropical regions, desert encroachment and soil degradation are major concerns. Different species of Casuarina, which undergo nitrogen fixing nodulation, improve the fertility of nitrogen deficient soils. Casuarina grows fast and yields up to $15m^3$ ha^1 yr^1 of wood, even under poor conditions of soils. It provides excellent firewood and can be converted into excellent charcoal. Some species of Casuarina can also stabilize coastal sand dunes in tropical and sub- tropical regions. In Senegal and China, one million hectares of plantations with C. equisetifolia have been established effectively (Gupta 2015-2016).

Development of Stress Tolerant Plants:
Tissue culture and transgenic techniques are used for the development of plants resistant to abiotic stresses. Salinity; acidity and aluminium toxicity are important among these abiotic stresses.

Plants Tolerant to Salinity:
Cell lines exhibiting resistance or relative tolerance to salt have been selected in many of the crop species and could be utilized for plantation on degraded lands suffering with salinity. These plant species include the following: *Brassica sp., Capsicum annuum, Cicer arietinum, Citrus aurantium, C. sinensis, Daucus carota, Hordeum jubatum, H. vulgare. Nicotiana tabacum, N. sylvestris, Oryza sativa, Prunus hybrids, Solanum tuberosum, Triticum aestivum, Vitis rupestris and Sapindus trifoliate.*
Some tree species exhibit moderate resistance to salinity and, therefore, could be utilized for plantation on saline soils. These include the following: *Prosopis spicigera, Butea monosperma, Terminalia bellerica,* etc. (Gupta 2015-2016).

Plants Tolerant to Other Abiotic Stresses:
Regenerants of selected lines can be utilized for growing plants in acidic soils with aluminium toxicity. Man Made synthetic crop 'triticale' is suitable for growing it on (1) acid soils in countries like Poland. Kenya, Ethiopia, India, Ecuador, Brazil, Mexico, etc.; (ii) dry and sandy soils (e.g. Savannah region of Brazil and some marginal lands in Asia); (ii) alkaline and calcareous soils (e.g. in Mexico, Spain, Portugal, USA) and (iv) mineral (e.g. Cu, Mn, Zn) deficient and high boron soils (e.g. Australia).

Mycorrhizae in Reforestation:
There is usually only a brief period which is favourable for growth on degraded lands that suffer from drought, poor nutrient supply and other abiotic stresses. If tree

seedlings do not get established during the window period, they are unlikely to survive. Mycorrhizae can improve seedling survival and growth by enhancing the uptake of nutrients (particularly phosphorus) and water, by lengthening root life and by providing protection against pathogens. The nutrients absorbed by the fungus from the soil are released to the host cells, and the fungus takes its food requirements from the host. Mycorrhizae are of following types: (i) ectomycorrhizae, (ii) endomycorrhizae. (Gupta 2015-2016).

Ectomycorrhizae rest on the root trees, e.g. pine, oak, beech, eucalyptus, etc. They absorb nitrogen, phosphorus, potassium and calcium. These help in transforming complex organic molecules into accessible forms, protect the roots from the pathogens, and produce growth-promoting substances (cytokinins). Trees in temperate regions form ectomycorrhizae and 70% plant species, including most of the commercial crops, growing in the tropical region, also have mycorrhizae. (Gupta 2015-2016).

Endomycorrhizae live in the roots of fruits and other crops, e.g. coffee, pepper, cardamom, and betel vine. They particularly help in phosphorus nutrition. The seedlings are inoculated with endomycorrhizae in the nurseries and then transplanted. Fungus strains of Azotobacter, Aspergillus, Azospirillum, Beijerineleia, and Glomus are used as endomycorrhizae. (Gupta 2015-2016).

Inoculants like VAM fungi for mycorrhizae may be supplemented with Rhizobium, Azotobacter (Rhizobium for legumes and Azotobacter for non- legumes) and phosphorus solubilizing microbes (PSM) for the better growth of the seedlings. The mycorrhizae formation depends on several factors, which consist of environmental factors, host physiology, soil microflora and microfauna, and finally on the inoculum. Similarly, experimental infection of micropropagated plants during rooting should increase their survival chances in the field, which is very important with plantations on degraded lands. In this connection, *Pisolithus tinctorius* mycorrhizae have been tested. Large batches of viable *P. tinctorius* inocula have been prepared and used, demonstrating the success of the fungi inocula for the development of mycorrhizae, leading to better establishment of plantations on newer and degraded sites (Gupta 2015-2016).

Microbes for Improving Soil Fertility:

The microorganisms are highly resistant to desiccation. Exopolysaccharides which increase the carbon in the soil are produced by microorganisms and it also contributes to soil stabilization (Weber et al., 2016). Genetic modification is done in cyanobacteria for enhanced carbon fixation, exopolysaccharide production and biomass growth; with other properties (e.g. Kamennaya et al., 2015). The use of genetically modified biocrust-forming cyanobacteria with these traits has the potential to further increase soil fertility and to reduce soil erosion, thus helps in the recovery of degraded dry lands. Rhizobium or members of actinomycetes genus *Frankia* can be utilized to induce nodule formation in many plant species, for improving soil fertility of degraded lands.

Nitrogen Fixing Bacteria for Nodulation in Legumes:

It is now known that Rhizobium forms symbiotic association in the roots of leguminous crops, which improves the productivity of soil through fixation of nitrogen. The 'legume- Rhizobium' system for restoration of degraded lands may involve the following steps: (i) produce inoculum of selected rhizobia strains on a (1) evolve effective and efficient caters of inoculum for field inoculation and suitable technique for rapid seedling and nodulation (Gupta 2015-2016). Major microorganisms used as nitrogen fixing bioinoculants are mentioned in Table 3.

Table 3: Nitrogen fixing bioinoculants and their target crops

Sl. No.	Bioinoculant	Target Crop
1.	Rhizobium(symbiotic)	Legume: chickpea, red gram pea, lentil, black gram Oilseed legumes: soybean groundnut Forage legumes: clover luceme Tree legumes; leucaena
2.	Azospirillum (associative)	Rice wheat, vegetables, sugarcane
3.	Azotobacter (free living)	Rice, wheat, sugarcane cotton sorghum, maize
4.	Gluconacetobacter	Sugarcane
5.	Cyanobacteria (oxygenic phototrophs)	Flooded rice
6.	Azolla (symbiotic)	Flooded rice

Source: (Kumar et al., 2013).

Trees associated with rhizobia can also be utilized for reforestation of degraded lands. Micro propagation with several leguminous species is being used for plantations in degraded lands. These tree species include one following: *Acacia nilotica, Albizia lebbeck, Dalbergia latifolia, D. leucocephala, Prosopis grandiflora, Cineraria,* etc. (Gupta 2015-2016).

Nitrogen Fixing Bacteria for Nodulation in Non-Legumes:

About 160 species of angiosperm are known to form root nodules with the actinomycetes included in the genus *Frankia* which facilitate nitrogen fixation in non-leguminous plant species and therefore can be utilized for land reclamation through reforestation because of high biomass production without the need of expensive fertilizers. Of this non-legume nitrogen fixing systems, (*Alnus spp*.) have been found to supply 12-300 kg N ha-1 yr-1 through leaf fall, excretion from roots, and nodule decays. Several species of *Alnus (A. crispa, A. glutinosa, A. incana, A japonica, A, rubra, A. sinuata, A. viridis*) have been used, where rooted plantlets, after their transfer to nitrogen free substrate, were injected with pure cultures of *Frankia*. In all cases, effective actinorrhizae was formed. These symbiotic associations of actinorrhizae not only fulfilled completely the nitrogen requirements of the trees but also helped in fixing nitrogen in the virgin soil, thus improving the fertility of the degraded lands (Gupta 2015-2016).

Restoration of Soils Contaminated with Heavy Metals:

Heavy metals act as toxicants, when present in larger quantities, reducing the plant life. These are cadmium, nickel, zinc, mercury, copper and lead. Nickel is released during extraction practices, and in large quantities present in the environment. Soil contaminated with arsenic affects seed germination, reduces root length and mass. Heavy metals damage the plants by evolution of active oxygen species, which shutdown the method of photosynthesis. Heavy metal concentrations in larger amounts in the soil can cause increased ethylene production, hinder root and shoot development, decrease CO2 fixation and lower sugar translocation (Kumar et al., 2013).

Plants have been modified genetically for detoxification of soils contaminated with (i) metals like mercury (Hg), aluminium (Al), and arsenic (As); and (ii) explosives like trinitrotoluene (TNT).

Mercury Detoxification:

Mercury is released as effluents, from various industries which utilize mercury in a variety of applications and cause mercury toxicity. Toxicity of Mercury led to epidemics in Japan in the 1960s. Methyl mercury contamination is now a serious environmental problem worldwide.

In 2000, *Arabidopsis thaliana* plants were genetically modified for a mercury detoxification pathway by using the two bacterial genes. The genes included merA for mercury reductase and merB for organomercurial lyase. The gene merA was also artificially synthesized by applying codon usage, and the synthesized gene merApe9 proved effective in releasing free mercury, which was less toxic.

$$R\text{-}CH_2\text{-}Hg + H^+ \xrightarrow{\text{mer B}} R\text{-}CH_3 + Hg\ (II)$$

$$\text{mer A}$$

$$Hg\ (II) + NADPH + H^+ \rightarrow Hg\ (0) + NADP + H2$$

The plants carrying these two genes could flourish on higher methylmercury concentration. These plants carrying these genes were also tolerant to gold (Au^{3+}) contamination.

Aluminium Detoxification:

The basic principle associated in the production of Al-tolerant plants is that citrate in the soil binds to aluminium, rendering it incapable of entering the roots. Keeping this in view, a gene for citrate synthase (CSb) was used for production of transgenic plants, which synthesized high level of citrate and secreted it into the soil through their roots, so that it will bind with aluminium, rendering it incapable of entering the roots, thus detoxifying the soil. Such aluminium (Al3+) tolerant plants carrying a gene for citrate synthase have been produced in tobacco, papaya, rice and corn, which exhibited tolerance to aluminium toxicity.

Arsenic Detoxification:

Production of tolerant and hyper-accumulating genetically modified plants in *Arabidopsis thaliana* was reported in November, 2002 (Nature Biotechnology). The bacterial genes (arsC, γ-ECS) were transferred, for arsenate reductase (ArsC) and for γ-glutamylcysteine synthetase (γ-ECS). While ArsC change arsenate to arsenite, γ-ECS change amino acids, glutamine and cysteine into γ-glutamylcysteine (γ-Glu-Cys) which is utilized for the formation of organic thiols (RS) including glutathione (GSH) and phytochelatins (PCs), in which arsenite binds. This increases tolerance of and hyper accumulation of arsenic.

$$AsO_4^{3-} + 2GSH \longrightarrow GS\text{-}SG + AsO_3^{3-} \qquad RS$$

$$\uparrow$$

$$Glu + Cys \rightarrow Glu\text{-}Cys \rightarrow \rightarrow \longrightarrow RS$$

TNT (an explosive) Detoxification:

Explosives that contaminate land and groundwater pose a serious threat to the environment, since they do not break down in the natural environment. For instance, trinitrotoluene (TNT) is associated with anaemia, liver damage and carcinogenicity. In the past, the only effective treatment of TNT-contaminated soils has been incineration, which produces unusable ash and causes air pollution. The transgenic tobacco with enhanced TNT-detoxifying ability was produced by transformation with the nitroreductase (NR) gene nfsl, isolated from Enterobacter cloacae, and tolerated TNT concentrations up to the TNT- aqueous solubility limits (~0.5 mM), although the wild-type controls exhibited phytotoxicity even at ~0.05rnM concentration. If this gene is utilized for transformation of fast-growing and large trees like poplar, this can provide a solution for clean-up of the TNT-contaminated sites.

CONCLUSION

Food security in India can be achieved by taking care of our precious resource, i.e. land, and paying attention to challenges such as climate change, integrated water and pest management, agricultural pricing and crop insurance. Hunger and child malnutrition are greater in rural areas than in urban areas. Various conventional and biotechnological methods can restore degraded land. Agricultural productivity, hunger, poverty, and sustainability are directly related. Therefore, improving the quality of land will increase agricultural productivity and can achieve food security in India.

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