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Land degradation neutrality in India: A dynamic process

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ABSTRACT

Soil erosion, forest fires, emission of fossil fuels, pollution, burden of diseases, disasters, demography, urbanization, transformations in living standards, epidemics and pandemics are challenging lives and livelihoods. Neutrality of land degradation, carbon footprints and climate change is called upon to harness sustainable development goals (SDGs). Integration of efficient use and conservation of soil, water, air quality/wind velocity, vegetation and biodiversity requires consistent attention of all stakeholders. The recent developments in land aggradations' by solar, wind, agriculture farming and their co-placement on the same unit of land, where ever feasible, were inadequately deliberated in the Webinar. Roles of glaciers, wetlands, sea coast, islands, unique niche agro-ecologies and biodiversity of vegetative cover needs further integration with the land degradation neutrality (LDN). Very unique, innovative and out of box enabling policies, programmes, governance, transparency and community participation cutting across soil, water, air and vegetation improved robustness of LDN. Circulatory economy of conservation, producing renewable energy, bio-manure, carbon management and green employment is emphasized for mitigating land degradation. Simultaneous occurrence of COVID-19 pandemic, floods, cyclones and locust swarm seems to have recalibrated new normal, digital platforms, lives, livelihood and LDN. Our aim should be to convert risks into opportunities and weaknesses into strengths.

1. INTRODUCTION

First of all, I appreciate the organizers for holding a Webinar when the entire world is pre occupied with the COVID-19 pandemic and may be that some of its solutions lie in the land degradation neutrality (LDN). India pledged to achieve LDN by 2030 by reclaiming, restoring, ameliorating, halting and mitigating eco-systems degradation of 26 Million hectares (M ha) in the Delhi declaration 2019. Resolving insecurity of land tenure, land titles, gender neutrality, carbon emissions, policy frame work, public and private participation were also promised to harness the opportunities. Degraded land estimates of India varied from 53.28 M ha of NRSA (1985) to 187.7 M ha of NBSSLUP (1994) and others agencies/stakeholders (NAAS, 2010). Harmonization of the maps of different agencies and sources by avoiding duplication or triplication of any pixel arrived at a figure of 104 M ha and the estimate of 96 M ha of the Ministry of Environment, Forest and Climate Change is the latest one. However, NAAS (2010) also used very old data sets whereas land degradation or aggradations is a dynamic process. A lot of transformations have happened after that and need to be factored in while realizing degradation neutrality. Dr Rattan Lal elaborated four major components i) soil, ii) water including glaciers, iii) air/wind, iv) vegetative cover and their complementarities and supplementarities in the eco-system. It appears that out of the four major factors, air/wind and glaciers got very little time of the Webinar. Dr Rattan Lal did mention about Ozone layer, but methane emissions of paddy cultivation, wetlands, enteric gases from ruminant animals, reclamation of peat soils, and ultra fine unstable carbon particles of smoke and other gases by burning of moist biomass are very significant issues of health. The other caveat is that in India, dry land eco-systems have been invested relatively more than the non-dry land ones. Although water is an essential input but poverty and out migration in search of livelihood is very high in the high rainfall, flood frequented and wet land ecosystem in the eastern as compared to dry lands in the western India. This paradox should engage attentions of scientists, resource conservationists, planners and policy makers.

Agro-ecological approach was adopted by the NBSS&LUP, Nagpur for land mapping, but it remained confined almost to the 7th approximate classification of a typical taxonomy. In addition to the physico-chemical characteristics of profile layers, farming systems are also driven by the marketing forces of new technologies, and was some how not integrated in the land use plans. For example, from the ecological view point, cultivation of water guzzling paddy in north-west India is un-desirable but it expanded at very fast rate due to assured marketing, and it seems difficult to convince the farmers for diversification in to other less water demanding crops. Economic considerations of paper and pulp industry led to the draining of Pacific coastal lands for plantations of fast growing tree species as raw material. On drying after draining, the peat caught fire, burnt millions of tons of carbon and degraded eco-systems. It is, therefore, necessary to include topics of policy, programmers, efficiency of investments, governance and community participation to realize transparency, integration with traditional knowledge and social audit etc. Keeping in view flow of natural fluxes within basins, sub-basin and watersheds, India has major agro-ecological zones of hills and mountains, irrigated, rainfed, deserts and coastal regions. However, communication, connectivity, expresses ways, rail line and power grids do not follow principles of contours and watersheds, and disrupt LDN. In that way, LDN is a very complex issue. However, I will be discussing under the typical four topics of soil, water / glaciers, and air/wind, vegetation, and expand with other interventions. New technologies and innovations of converting threats into opportunities, and wastes to green employment, wealth and clean environments will be summarized.

2. SOIL

Soil is generally eroded by rainfall, run off, wind and mediated by topography, vegetative cover, conservation farming practices, policies, programmes, community participation and market forces.

Water erosion: It consists of splash erosion, sheet erosion, rill erosion, gully erosion, landslides, stream bank cutting, sediment transportation and deposition downstream. Soil erosion is highest in hills and mountains eco-system with very contrasting management practices in the eastern and western Himalayas (Samra *et al.,* 1999). High rainfall, typical geology, steep slopes, lack of sufficient vegetative cover and more than 200 low intensity seismic shocks per annum are the major reasons of land degradation. Net cultivated area is only 12% and forests are very crucial for cycling carbon, nutrient and water for sustaining its productivity. Tree felling and transportation of timber outside forest is already banned in the fragile hills and mountains, but participation of local community for fighting forest fires has diminished over the period. Construction of roads, rail and transmission lines have changed land degradation and aggradations processes.

Land degradation in other un-irrigated agro-ecologies with milder slopes of land is managed by contour bunding, land shaping, contour cultivation, crop cover, runoff harvesting; it's recycling for irrigation, mixed cropping, agro forestry and live stock rearing. Soil erosion in the plains is managed by adequate land leveling with raised field bunds, irrigating land and establishing crop canopy before the rains.

Soils of coastal regions are also being degraded by sea waves, cyclones, super cyclones and *tsunami,* leading to evacuation of population and live stocks to shelter homes many a times which is an intensive disruption in the livelihood. A very long, properly designed and successful shelter belt was planted in 1964 along the sea coast of Orissa in east India. It was very effective against coastal land degradation by hurricanes, cyclones and super cyclones. Mangroves growing along the sea coast have very unique mesh net work of propped up root system which hinders sea waves, typhoon, hurricane and prevents land degradation very effectively. Overall, various kinds of engineering measures, cultivation practices, farming systems, National Disaster Response Force (NDRF) and army are available for immediate relief of disasters. Dedicated financial resources are provided in the annual budget to provide immediate relief, repair and restore damages of housing, roads, railways, electricity, communication and other infrastructure. However, frequency and intensity of such episodes are increasing over the years due to global warming and climate change.

Shifting cultivation: Slashing and burning of natural vegetation on steep slopes, cultivating and shifting to new sites within a few years after the soil has eroded or degraded, and extending land degradation to fresh sites is very common. Ownership of the land or land titles is very unique among the tribal's and is generally regulated by tribal heads in many cases. This required very unique, innovative and out of box solutions against land degradation. Permanent settlements on the traditionally irrigated terraces, protected cultivation under new land use policy in Mizoram, plantations of fruit trees, fast growing and nitrogen enriching *Alder* trees under NEPED scheme was a positive experience. Plantations of palm oil under ISOPOM scheme, Tung oil shrub (*Vernicia fordii*, China native tree), rubber, economical timber trees of *Dalbergia sisso*, teak (*Tectona grandis*) of long durations and various other schemes also binded tribal's permanently to a given site and avoided land degradation. Tribals' and other long term (more than 50 years) forest dwellers were also given land titles on the same principles. They were also expected to invest for improving land conservation and higher productivity, and impact analysis on land degradation seems to have not been reported/ presented adequately.

Mining of ores, minerals, soil nutrients by intensive cropping systems also dislodges soil massively; deteriorates over all environment, soil health, water quality, and land

productivity. Rehabilitation of mine spoiled land by bio-engineering and communities' participation especially on common land has been demonstrated at many sites but much headway could not be made in very large and commercial mining projects due to various reasons. Brick kilns normally remove upper 1-2 metre upper fertile layers of soil, and now blocks are being made from fly ash with high porosity to insulate buildings with a strength more than clay bricks.

Wind erosion and shelter belts: Aridity, wind velocity and lack of vegetative cover erode soil particles, transport air suspended soil, shift sand dunes, deposit sand around houses, block roads, railway lines, water channels, canals, and desiccate soil moisture (Mertia *et al.,* 2006). This kind of eco-systems degradation is happening in India both in hot (around Rajasthan) and cold deserts of Leh and Ladhakh with livelihood being derived mostly from migratory live stocks, rare dyes, juices (Seabuckthorn beverages), medicinal plants, herbs, thorny shrub and trees of unique physiology. Species such as *Bergenia ligulata, Cinnamomum zeylanicum, Crocus sativus, Elettaria cardamomum, Emblica officinalis, Ficus religiosa, Mangifera indica, Punica granatum, Santalum album, Spondiax axillaris, Terminalia belerica, Terminalia chebula,* and *Zingiber officinale* is a unique biodiversity. Some medicinal stones (Shilajit - an Ayurvedic medicine), minerals and salts are also unique to these deserts of India. Chequered low barriers of grasses, vegetative wind breaks of tall grasses, bushes and trees reduced desertification and degradation. Planting of vegetative shelter belts along canals, distributaries, (Photo 1), field boundaries and around orchards, especially in deserts, was very effective against damages of wind storms, cold and heat waves. Wind breaks, leveling of sand dunes, better canopy and crop cover reduced blowing of sand and shifting of sand dunes.

Converting wind velocity by wind turbines into electricity, its related economic goods and services reversed land degradation and rather realized aggradations, especially along the west coast of India. Installation of solar panels in the form of above ground arrays also have potential to break or dissipate wind velocity and moderate erosion, sand saltation, sand dunes shifting, encroaching upon vegetation and degrading land resources. Transporting of Himalayan water up to Jaisalmer and Jodhpur regions of Rajasthan has reversed the desertification.

Cold dessert of Leh and Ladakh is quite distinct than hot desert (of Rajasthan and surrounding areas) and pockets further down south. Leh and Ladhakh is the highest inhabited plateau of the world known for its inaccessibility, remoteness, cold climate and least populated area in the Indian sub-continent. Ladakh's fauna and flora exhibits several interesting characteristics which have evolved as adaptations to the region's extreme climatic conditions such as seasonal migration and hibernation. Thick fur and bushy tails, large nostrils are very common among the animals. Nearly one third of the recorded flowering plants are used by Amchis (medicinal practitioners' of Mongolia) in the region. Over 100 species have also come under threat due to excessive extraction, habitat degradation and economic considerations. There is a huge scope of cosmetics, perfumes, pharmaceutical and aromatic industries in Ladakh, but sustainability is a major concern.

3. WATER/ GLACIER

Rain and snowfall re-cycle water among land, atmosphere and ocean, and washes air pollution. Its storage in glacier and dams regulate floods and ensure water supplies for domestic and industrial needs throughout the years. India has about 5 M ha of snow cover/glaciers with vast hydrological resources. There are several reports of their excessive melting and retreating due to global warming. It is also raising sea levels, and inundating and degrading coastal land. Over flow or bursting of Chorabari glacial lakes in 2013 above Kedarnath temple in Garhwal Himalaya, India devastated land and created havoc downstream along river banks by flooding downstream plains. Such drastic events may change LDN in many dimensions of lives and livelihood.

Photo 1. A typical shelter belt along a canal in the Rajasthan desert, India

Precipitation plays significant role in weathering of rocks or soil formation, erosion, transport of sediments, alluvium deposits, and growth of natural, cultivated and planted vegetation. Sub-surface storage as ground water also ensures water supplies during lean periods. Its related economic goods, services and environmental externalities are tremendous. In that way it is an important driver of LDN. However, frequency and intensity of cloud bursts, thunderstorms, floods, water laden cyclones, super cyclones, droughts, desertification and associated land degradation as well as aggradations is going up due to global warming.

Kinetic energy of rainfall dislodges soil particles and transports or re-distributes them along with the surface flow all over the slopes. It creates rills; concentrated flow velocity erodes beds of channels, and washes away stream and river banks. Deposition of transported sediments due to loss of water velocity down streams is leading to formation of very fertile alluvial soils *i.e.* degradation in the up streams is translated into aggradation of alluvial soils downstream in foot hills of mountains, and these dynamics have been going on for millions of years. Highly concentrated sediments in flood water diminish bio-diversity of fishes and other aqua culture. Floods also damage crops, animals, wildlife, infrastructure, and houses, and spread diseases. It is a very dynamic complex cycles of LDN.

Irrigation smart Systems and Land Degradation: Upper Bari Doab Canal (UBDC), one of the oldest canals in India, built in the year 1693 for carrying water of river Ravi from Madhopur in India to Lahore (now in Pakistan). It witnessed cycles of high productivity, water logging, salinization, land degradation, drainage, reclamation, restoration of productivity and over exploitation of ground water over 327 years. Even recent transport of Himalayan water by 650 km feeder plus main canal and 3454 km distributaries of Indira Gandhi canal into Rajasthan deserts since 1983 also witnessed very rapid dynamics of LDN (Photo 1). It led to leveling of sand dunes, crops diversification, better vegetative cover and overall land improvements. All these and other interventions induced *in-situ* land aggradations and halted shifting of sand dunes to neighboring states of Haryana, Delhi and Punjab. Ultimately, it also raised water table due to faulty inefficient irrigation systems, and land degradation by salinization processes returned back in the canal commands and surroundings. Elsewhere, over exploitation of good quality ground water due to rural electrification is also culminating into land degradation and impinging upon SDGs. Increasing occurrences and intensity of floods and droughts due to climate change are going to modify land degradation processes both in wet and dry lands.

Smart irrigation systems: Land degradation due to inefficient and excessive flood irrigation as well as over exploitation of ground water can be resolved by the most efficient conservation micro irrigation. Old canal irrigation acts have been amended in many states to modernize irrigation system to halt and reclaim irrigation related land degradation. Sufficient public and private investments into underground water conveyance, distribution, sprinkler, drip applications (Photo 2) and diversification in the existing old canal commands was prioritized about ten year back. Projects are under different stages of construction and completion, and outcomes are awaited.

A *de novo* micro irrigation system at Synchore, Barmer (Rajasthan) was constructed at half of the water duty norms of flood irrigation systems in the past. All water conveyance and distribution channels up to storage tank (*Digi)* were constructed with half the specifications of the civil works. A pumping station along the storage tank (*Digi*), underground plastic pipes and risers for drip irrigation were provided in the command. Each riser served 3-4 farmers, and onward flexible conveyance for on ward distribution was the

Photo 2. Smart, drip irrigation and plastic mulching

responsibility of group of 3-4 farmers. A dedicated supply of electricity for operating the system and drinking water services was also part of the irrigation project. Water charges were collected by the farmers associations, 50% was passed on to the Irrigation department for maintaining the upstream system upto *Digis* (concrete lined water storage tanks) and remaining 50% was utilized by the Farmers Associations. However, there are reports of unauthorized lifting of water by powerful lobbies, other mis management practices and, if so, it will negate LDN.

Asia's largest drip irrigation PPP project in Ramthal district Balakote, Karnataka: This project was constructed in Public Private Partnership (PPP) mode by Jain Irrigation Systems Ltd. (India) and NETAFIM (Israel) for 60,000 ha by lifting water from the Krishna river. Farmers are depositing water charges in advance @ ₹1300 acre^{-1} and system will be handed over to the farmers after five years. This automated system has 85% irrigation efficiency as compared to 35% of the traditional system. There is 50% power saving, higher efficiency of fertilizers' use, reduced soil erosion and soil health is safe. It is changing the entire ecosystem at a very fast rate.

Rainfed regions: It consists of un-irrigated, high rainfall and flood prone areas in the eastern coastal regions as well as low rainfall and drought frequented western India.

High rainfall region: Although water is a prime mover of growth engine, but unfortunately poverty is more in the high rainfall and water rich eastern region as compared to drought prone western region. This contradiction is due to lack of proper management of LDN, human resources, enabling policies, programmes and governance in the eastern part of India. Harnessing of floods and their moderation in the east is also constrained due to lack of its management in the upstream neighboring countries. Several attempts in channelizing of flood flows with bio bunds, aquaculture, agro-forestry, raised and sunken beds, livestock rearing and post flood farming practices are there to achieve LDN. However, up-scaling with efficient investments, marketing, input supply chains, transparency, community participation and good governance is called upon to reduce poverty, out migration of labor and secure lives and livelihoods *in-situ*. Recently, commercial cultivation of a prickly water lily (*Makhana* or fox nut or *Euryale*) and cultivation of sub mergence tolerant rice has improved upon land uses of the eastern and other flood frequented agro-ecologies.

Low rainfall region: By default or politically, this region of low and erratic rainfall got higher priority of setting up institutions, schemes and investment portfolios of dry land desertification and transferring of Himalayan water for augmenting irrigation and other water supplies. Fortunately, this western region is also having highest potential of renewable wind and solar energy right from Leh to downward south, and latest technologies have made it the cheapest source of electricity-another driver of accelerating growth. Impact evaluation on LDN of dynamically changing transformations is needed to make some mid course corrections, if any. Desert and semi-desert ecosystems have potential of special niche crops of bio dyes, spices, condiments, medicinal herbs, cotton and multiple uses of *guar* gums (*Cyamopsis tetragonoloba*) of organic nano particles. The *guar* gum is known for its multiple uses, and has more than 200 patents of products, derivatives and processes. This commodity is listed as number one on the traded commodity list of future markets. Traditionally also it was on *Satta* (un- regulated future market) in Jaipur (Rajasthan) market. Recently it was used as thermo stable lubricant in drilling of shale gases, and its prices went up three times and area under cultivation expanded. In the mean while, China introduced its synthetic substitute, and *guar* gum prices crashed with serious implications of livelihood of the farmers. Bt cotton increased land productivity and decreased input of insecticides and pesticides for meeting raw material demands of commercialized textile industry. Diversification into non-Bt soyabean (*Glycine max*) with commercialization of its oil extraction, protein rich food products and export of oil cakes improved land productivity tremendously. Technology of these three crops or commodities made a difference in land use, lives and livelihoods in the relatively low rainfall western India. Similar kinds of alternative and unique land use potentials of high rainfall region inflicted with poverty and labour out migration need to be promoted.

Wetland ecosystems: In India, they are spread over 15.26 M ha, and provide lives, livelihoods and many other ecosystem services to the local community (Anonimous 2004). Wetlands are major sink of carbon, stabilization of CO_2, CH_4, N_2O, other green house gases and recharging groundwater. Excessive flows of silt, untreated sewage, nutrients and many drivers of climate change are degrading wetlands. Excessive growth of weeds due to water purification led to formation of compact floating pads of biomass. Local community puts some silt over them and grows vegetable under very good regime of moisture and peat. They are called *Phumids* in the local parlance. Some of them have made even thatched sheds, especially in Dal and Lok Tak lakes, go there by boat, catch fish whole day, defecate into lake and pollute water. They have also become hiding place for smuggling to Bangladesh through the shared Lok Tak lake, by goons and other bad elements. The construction of major hydraulic projects upstream of Chilka Lake in Odisha has altered the flow of water into the lake. The long shore sediment transport along the coast of Bay of Bengal is estimated to be 0.1 million metric tons annually, and tends to shift the mouth opening to the sea every year, adversely affecting the vital tidal exchange. India has mapped and identified 130 wetlands for their priority restoration.

4. AIR / WIND

Air as a part of land eco-system is essential for breath-

ing. It spreads winged seeds of natural vegetation as well as diseases. Wind blowing, gales, hurricanes, cyclones and super cyclone also inflict swear damages to trees, orchards, blow away roof top sheets and damage many other infrastructure. Wind is also a source of energy, and wind powered grain mills were used as early as 1854. Wind turbines for electricity generation were invented in 1887, and grid connected wind farms came up since 1980s in USA and Europe. A floating wind turbine off the coast was also installed in 2009. Currently wind farms are a very common site along the western coast of India. In fact, Leh and Ladakh cold desert has the maximum potential of wind and solar farming. However, infrastructure of power evacuation to meet the main land demand is lacking and local power consumption is insignificant. All these developments are both degrading as well as improving the land use systems in India.

Air pollution: In 2017, air pollution caused 1.24 M premature deaths constituting 12.5% of the total deaths in India. There was also a loss of 38.7 M *i.e.* 8.1% of the total disability adjusted life years, and life expectancy was reduced by 1.7 years (Lancet Planet Health, 2019). Currently, burning of surplus crop biomass, organic matter of municipal solid waste dumps and decomposition of agro and industrial wastes are emitting greenhouse gase (GHG) (Table 1) and adding to the burden of the diseases (Hiroko *et al.,* 2012; Nawaz *et al.,* 2016). Except rice burning, all other emissions are inevitable and are un avoidable being part of the processes. However, these can be captured and harnessed by digesting anaerobically, taking away methane (CH_4) and recycling all inorganic nutrients retained in the digestate. It will reduce emissions, provide renewable energy without loss of nutrients, and soil health will be as good as in the *in-situ* incorporation and mulching. We will be harnessing global warming potentials as economic goods, services and green employment of our waste to wealth policy. It will also reduce burden of diseases of human and soil health.

This burden, especially of respiratory diseases, is now being aggravated by COVID-19 pandemic. However, surplus biomass and organic wastes are also a source of renewable energy to mitigate global warming, climate change and desertification as detailed below:

Wind, solar, inter crops farming systems and their co-placement: These systems are akin to the multi layered agro-forestry farming which convert hardly 4-5% of solar radiations in to energy by photosynthesis. Energy conversion efficiency of photo-voltaic is in the range of 20-30%, and of wind turbine more than 60%. Therefore, solar and wind farming is 4 to 15 times more efficient than the cropping, ago-forestry and forestry system for capturing energy and carbon (Photo 3a and 3b) and is a big challenge to the breeders. One acre of land under solar, wind or their co-farming produces electricity worth ₹ 7.5-8 lakh annum^{-1}.

Co-placement of crops on the ground, solar panels a few meter above ground and wind turbine at about 100 m height on the same unit of land maximizes land use of three in one (Photo 3b). Of course investment rates are high in solar and wind farming as compared to agriculture farming but they are commercially and economically viable with tremendous land aggradations' potentials. A minimum distance between wind turbines and arrays of solar panels is essential to avoid self shading, interferences among the wind turbine blade, and both inter space and partially shaded under space can be used for inter cropping. It also complements conservation of wind erosion, rainwater harvesting, its recycling from sloppy solar panels and overall improvement of micro-

Table: 1
Comparison (LCA) of GHG emissions of different systems of managing muncipal and other wastes

S.No.	Practice	CO^2eq (kg) ton^{-1} of waste
1.	Rice straw burning	3490
2.	Land fills	224
3.	Pit composting	240-400
4.	Co-digestion of industrial waste of sewage sludge	156
5.	Wheat straw mulching upland wheat	220

Photo 3a. Inter cropping in between arrays of solar panels, rainwater harvesting from inclined panels and recycling at CAZRI, Jodhpur

Photo 3b. Co-placement of Solar Panels, Wind Turbine and Inter crops (Three in one)

environment. Electricity tariffs @ of ₹ 3 Kwh^{-1} of solar and wind power is cheaper than ₹ 4-5 Kwh^{-1} of coal and hydropower power in India. Solar farming requires land @ 2 ha MW^{-1} and wind farming @ 4 ha MW^{-1}. It will be most intensive land use for green employment, live and livelihood generation. Private investments are pouring in and going to reduce wind erosion, sand dunes shifting, and improve micro-climate, bio-diversity and land productivity even in the deserts. Rainwater harvesting from solar panels for their washing and irrigating of crops in between solar arrays and under the panels constitutes its multiple uses. Moderating of wind velocity by converting it into electricity improves upon moisture regimes, and groundnut is being inter-cropped under wind mills along the western coast of India. Roads constructed for a lying out and repairing or maintaining of wind mills and solar systems has improved connectivity for harnessing alternative market driven land use systems.

Alternative uses of waste land for planting of Jatropha (*Jatropha curcas*); *jojoba* (*Simmondsia* chinensis) and oil bearing trees on wastelands for replacing polluting diesel have not succeeded in India. The new bio-fuel policy 2018 of India provided incentives, assured tariffs and marketing of bio-fuels to minimize emissions, global warming, desertification and land degradation. Unlike Europe, Scandinavian countries, Canada and south America, non-timber biomass is very limited in India. Therefore, spoiled grains, surplus crop biomass, agro, domestic and industrial organic residues being burnt can be used as feed stocks for producing renewable bio gases, bio-fuel and bio manure for recycling of carbon and nutrients contained in the bio or organic mass (Samra, 2019). Meta analysis of 39 publications by Lehtinen *et al.,* 2014 and 176 papers by Chang *et al.,* 2014, established that incorporation of straw always improves soil health but also emits green house gases. Similar observations have also been made about mulching (surface retention) by Nawaz *et al.,* 2016. These inevitable emissions can be harnessed as renewable energy of bio gas. Surplus straw of cereals, mustard, sugar-cane trash and municipal organic wastes are being burnt, polluting air and increasing global warming with loss of soil carbon and nutrients leading to land degradation. Anaerobic digestion or methenation can convert these emissions into renewable energy and digestate will ensure health of soil rather slightly better than incorporation and mulching. The latest technologies of anaerobic digestion and others are generating commercially viable several economic goods, services and green employment. In anaerobic digestion, about 50% of the feed stock (biomass) is left out as residue or digestate of manure consisting of recalcitrant carbon and most of the nutrients (Photo 4 a, b, c and d).

Manure recycling ensures sustainable soil health, fertility and productivity of agriculture without land degradation. A large scale commercial plant using 300 tonnes of paddy straw per day with 8 digesters is going to be commissioned very soon. Each digester is of 10,000 M^3 capacities, 22 m height and 26 m diameter. It will produce 33 tonnes of CNG and 150 tonnes of bio manure per day. Indian Oil Corporation Limited has also signed for the purchase of this gas which will be sold at their petrol pumps. It can use other sources of bio or organic mass and will be commissioned in December, 2020 at Sangrur, Punjab by a German company.

Biogas consists of methane (55-70%), carbon dioxide (20-22%), traces of other gases and moisture. It removes most easily decomposable carbon which otherwise is also lost during curing (of the manure in pits or in the open heaps), mulching and decomposition after *in-situ* in corporation with happy seeders. It is altogether a different game of land aggradations or degradation of natural resources of a circulatory bio-economy.

5. VEGETATIVE COVER AND LAND USE SYSTEMS

Forest fires, burning of crops residues and municipal wastes makes vegetative cover very fragile and dynamic component of LDN dynamics (Ahmed *et al.,* 2017).

Multi-layered vegetative cover of trees, shrubs, grasses and crops acts as wind break and also absorbs soil erosion triggering kinetic energy of rains. Through fall, stem flow of rainwater and litter fall on the ground moderates dispersion, hydraulic and erosion processes. Soil conservation in the catchments of river valley project and flood prone river (RVP and FPR) is in progress since 1961-62 in one form or the other to prevent siltation of dams and ensure extended flows of rainwater. Degraded forests were also planted elsewhere with *Eucalyptus, Gliricidia, Prosopis, Leucania lecocephala, Casurina* and native species of *Pongamia pinnata, Tamarindus indica, Gmelina arborea, Wrightia tinctoria, Syzygium cumini, Albizia lebbeck, Terminalia bellirica, Azadirachta indica* and *Ficus.* Improvements in the forest cover in India has been reported in India State of Forest Report (2019). However, degradation of forest ecosystems by high intensity of forest fires due to climate change has also been reported in India (Ahmed *et al.,* 2017).

(a) Anaerobic digestion

(b) Digestate coming out of the digestor

(c) Compressed methane gas for sale

(d) Digestate cured as manure

Photo 4. Pilot plant of producing methane and bio-manure from the animal dung and is working satisfactorily for the past 4 years

Photo 5. Digesters for producing biogas and bio-manure from bio mass and other organic wastes

Plantations of commercial species of *Eucalyptus* and *Poplars* for paper mills, plywood and synthetic wood industry was taken up even by the farmers on field bunds as well as in block plantations with inter cropping. It took over the paper and pulp market of grasses (*Eulaliopsis binata*) in the Shiwaliks and led to the collapse of many joint forest management committees. Several sylvi-pasture systems were demonstrated for gravelly land in the foot hills of Shiwalik but could not be scaled up due to ownership problem of these degraded lands.

Plantations of rubber, teak, nitrogen and carbon enriching *Gmelina arborea, Alnus nepalensis*, and fruits did resolve degradation of shifting cultivation in NEH hilly region. In India, waste lands were given almost free to individuals and organizations for raising plantations but were misused for construction of private schools and other purposes. Plantation companies, especially of teak, grew like mushrooms; the public invested with assured returns but the companies disappeared from the scene without ameliorating LDN. It turned out to be a big scam. Tree plantations co-operatives on the waste lands, like that of very successful milk co-operatives of National Dairy Development Board (NDDB), were promoted in Gujarat, but did not make much head way in LDN.

Timber transportation restrictions, moving timber saw mills far away from the forest boundaries, Forest Rights Act-2006 and Compensatory Afforestation Fund Rules, 2017 are expected to protect and add to the vegetative canopy cover. All these interventions are going to improve cycling of carbon, nutrients and other fluxes.

Thorny Prospis vegetated barren lands in arid, water logged and saline environments. It also provided fuel wood, small timber, feed and fodder related services to the local communities. Plantations of fresh edible dates in Bhuj

(Gujarat) and Jaisalmer (Rajsthan) with their branded marketing is aggregating land uses. There are also some very unique and niche land uses as mentioned below.

Banni grasslands reserves form a belt of arid grassland eco-system on the outer southern edge of desert of the marshy salt flats of Rann of Kutchh, in the Gujarat state of India. These are seasonal wetlands; salty water table is shallow with floating fresh water at the top layer which is normally skimmed with indigenous methods. This ecosystem is known for its rich wildlife, biodiversity and a special breed of buffalos which is very tolerant to poor quality of water and fodder. Well organized milk collection centres, ensured veterinary services, supply of feeds and higher income of the dwellers are a success story. They are currently legally protected as reserve forest but are degrading at a fast rate. This challenged ecosystem originated after the earthquake of 1819 by shifting course of a river flowing through Sindh in neighboring country of Pakistan and illustrating typical land degradation.

Sundarban delta West Bengal: It is a confluence of three rivers having tidal halophytic mangrove forest (*Rhizophora mangle*) growing with propped up (aerial) root system of a fine mesh work. Even strong sea waves get decayed after entering into this mesh work of roots and conserve coastal soil. It also enriched environment with carbon and other nutrients cycling for supporting high productivity of fish and other aqua culture. It is also a UNESCO world heritage wildlife site. There are also many settlements scattered around. It is a fragile eco-system very sensitive to climate change and LDN.

Mangroves have above ground roots (aerial roots) to prevent soil erosion along the coast, and there are also grasses with below ground stems (*Rhizomes*) who stabilize depositions of fresh sand and initiate colonization of vegetation. Giant Reed or Nara (*Arundo donax)* has colonized sand brought down by flash floods in the lower Shiwaliks. It is a tall perennial grass with massive *rhizomes* who compress the sand while growing, and fine root system holds the sand against the erosive forces.

Padasekhram (limited collective farming) agro-ecosystem of Kerala: Coastal Kerala has very unique soils having a rare combination of high acidity (low pH), salinity, rainfall, and is cultivated below sea level, something like that of in Netherland. Farmers make a group of 100-200 members and make an earthen bund around a block of about 50-100 ha collectively to prevent entry of saline sea water. This block of land gets filled up with very pure quality rainwater which absorbs high salinity of soil and is pumped out collectively. It washes out soil salinity and also raises soil pH within the range of rice cultivation. There are also medicinal rice varieties of black and other colors, tolerant to high salinity, acidity and are sold at premium prices. It is a sort of limited collective farming and has been declared World Heritage Agriculture also. It is a sort of seasonal wetlands. However, it is degrading very fast rate due to lack of maintenance and interest of members due to inflow of foreign remittances in Kerala, and is a unique dynamics of LDN.

Lakshadweep islands: It is a group of 36 islands, and is the smallest union territory of India. According to the India State of Forest Report (2019) the tree cover in the union territory is 90.33% of its total geographical area (TGA). About 82% of the tree cover is privately owned coconut plantations, mangroves and few others. There are no endemic plants in the Lakshadweep islands. The other natural flora is a typical of coral habitats. The fragile agro-biodiversity of Lakshadweep islands remains undocumented. Running length of the coasts of these scattered islands is very large and its erosion is the major concern. It also has a vast lagoon of 4,200 sq km. with sandy beaches and abundance of marine faunal biodiversity. The lives and livelihoods of inhabitants of Lakshadweep based on fishery and tourism is very fragile.

Andaman and Nicobar islands: It is a group of 550 islands with 94.68% of its TGA under forest with very dense canopy (68.3%) and dense canopy (8.3%). Out of over 2500 angiospermous species so far known from these islands, about 246 are endemic. The Andaman islands have 35 and the Nicobar islands have 21 true mangrove species known for conservation of wet lands. It is also a hotspot of biological diversity and deserves the focus of LDN. These islands are highly different than the Lakshadweep islands in many respects.

Tribals lands: There is more than 104.5 million tribal populations lagging behind the mainstream in India. Minor forest products and subsistence cultivation of crops provide lives and livelihood security. Growth in their population and inevitable change in their lifestyle has gone beyond the traditional carrying capacity of the land resources. Committed financial resources and decentralized decision making under Left Wing Extremists division since October, 2006 improved communication and connectivity by investing into transmission towers, mobile phone services, rail lines and roads in the inaccessible dense forests.

Classical tribal area of NEH was prioritized for international trade under the look east policy. Integrated check post at Moreh (Manipur), Agartala (Tripura), Petrapole (West Bengal), Jogbani (Bihar) and Raxual (Bihar) on international borders have been constructed by Land Port Authority of India. Its related road, railway and other infrastructure is exposing tribals and fragile ecosystem to the trade, which may accelerate erosion in these young hills, leading to over exploitation and land degradation.

Tribals' and other forest dwellers living for more than 50 years have been given titles of forest land by an act passed in 2006. The idea was to prevent their frequent migration and spreading out land degradation. They were

also expected to invest for permanent improvements in the land. However, all these investments and their governance are a very deep political economy of vote banks and realization of LDN has to be watched and analyzed carefully and periodically.

6. CROSS RELATED ISSUES

In addition to the fundamental four components of LDN briefed above there are other related developmental interventions cutting across the four, supplementing and complimenting LDN dynamics.

Transport logistics: Express/motor/freeways, bullet trains, speedy and dedicated railway freight corridors are being built across India with large scale investments. Eight to ten lanes of express ways and dedicated rail lines net works are mostly raised from the ground with under passes or flyovers to realize zero crossings and require large chunks of land, including for soil borrowing pits. It is drastically changing land use system, land prices, possibilities of crops diversification for agro-processing due to better connectivity and access to markets. Roads and rail lines alignment do not follow contours like in the construction of canals, bunds, delineations of basins, sub basins and watersheds. It is a massive interference with the natural flows of surface and sub-surface fluxes of water, air, seeds or propagules of natural vegetation, carbon and nutrients. It also involves cutting of trees and re-afforestation of shelter belts along roads and rail lines across India. Some of the modern express ways can also be used for emergency landing of aeroplanes and in that case tree planting along the high ways may not be feasible. All these interventions will certainly accelerate dynamics of LDN.

In India, real estate and industry has the highest priority of land utilization. Orchards of grapes and vegetables cultivation in the peri urban of Hyderabad and Bangalore, litchi around Dehradun, sand pear of Amritsar and in many other cities have been replaced by the buildings. Similarly, I could not find LDN analysis of 232 special economic zones in operation and 351 notified after SEZ Act-2005.

Policies, programmes, community participation and governance: Many learned speakers mentioned several acts, policies, programmes, interventions of different agencies, their co-operation and investment portfolios. However, impact analysis of land degradation and aggradations were not presented in most of the cases. Impact evaluation is necessary to make amendments, if any, for harnessing complementarities of convergence, co-ordination, integration of resources and solutions. A few months back in June, 2020, three laws have been passed by Government of India (GoI) and ordinances issued for privatization or PPP projects on following counts:

i. One market across all India
ii. Amending of essential commodities act for removing stock limits.
iii. Land leasing, contract farming and land titling.

There are lobbies for and against these acts and ordinances. However, it will have definite implications on land use and degradation of natural resources. The corporate philosophy is competitive marketing with animal instincts and most of their social corporate responsibilities also revolve around their business models. Sustainability, degradation and aggradations' of land resources generally have low priority for them. For example, prawn and pearl culturing along the sea coast was invested by the companies in the past. They degraded coastal eco-system. Prawn diseases spread all round and corporate left after having recovered their investment and targeted profits. In India about 85% of land holdings are small with insignificant bargaining powers and experiences of dealing with complicated contracts bargains. Availing legal services at this small scale are not viable. Degradation of natural and human resources may be considered in the formulation of rules of these acts before introducing the new policies. Enabling and incentivised policies, acts, programmes and investments in to conservation of forest, natural resources, environment, biodiversity, wildlife, participatory processes, management of calamities, disasters, and biological pandemics are very important. There is no substitute of good governance.

Simultaneous occurrence of COVID-19 pandemic, floods, cyclone and locust swarm: Reverse migration, lack of growth, unemployment, food and nutritional security issues of lives and livelihood have re-discovered importance of land resources or SDGs. Agriculture system remained resilient to pandemic and we should not become complacent about LDN. It has led to new norms and digital platforms. For maintaining social distance, Punjab Government almost doubled the number of grain markets by declaring all rice mills also as grain markets. Previously farmers use to spend one or two nights in the *Mandis* (markets) to sell their produce. However, during pandemic they came back by the evening and their confidence in the cultivation of land degrading mono cropping system of wheat-rice has gone up. Except wheat and rice, market of most of the perishable commodities collapsed and diversification agenda from water guzzling rice crop stands postponed for the time being. Social distancing brought in unique, innovative and out of box normal, digital platforms and mobile apps for regulating arrival of grains and farmers in the grain markets. Because of reverse migration, the labour intensive transplanting of paddy has been replaced by direct seeding practice with savings of over exploited ground water. In fact these kinds of transformations have happened in almost all walks of life. Webinars like this one, on-line conferences, training and extension are proving cheaper and convenient. There is a healthy competition to improve upon the apps and will stay even after the pandemic. Demand and market for 5G or even 6G platforms, apps, smart mobile phones and table devices is growing exponentially. Jio platform of Reliance has already attracted foreign investors like Google

and Facebook to capture the emerging market of new digital platforms. All these developments will impinge upon land use changes, management of degradation as well as aggradations' processes.

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