1.0 Introduction

Land degradation is a major threat to our food and environmental security of India. Out of total geographical area of 328.73 million ha in our country, about 120.40 million ha is affected by various kind of land degradation. Among these about 17.93 million hectare areas are suffered from problems of soil acidity. Growth, biomass and productivity of any crop are affected in acid soil due to low pH with very low cation exchange capacity and low levels of available nutrients; as a result the resource use efficiency of the crop on such soil is low. Acidic soil environment (pH < 6.5) affects plant growth directly or indirectly by influencing the availability of plant nutrients, particularly phosphorus, secondary nutrients (Ca, Mg) and micronutrients (Mo, B and Zn), reducing microbial activity and creating toxicity of Fe and Mn (Al in some cases). The maintenance and management of acid soils are thus very important to obtain higher resource use efficiency and productivity of the crop on sustainable basis.

Acid soils are formed in India mainly due to:

- Acidic parent materials like acid granite rocks, in the process of soil formation, render the soil acidic.
- Leaching of bases caused by heavy precipitation.
- Use of acid forming fertilizers. e.g. Nitrogenous fertilizers like ammonium sulphate and ammonium nitrate
- Drastic weathering of rocks associated with hot humid climate and heavy rainfall.
- Laterization, podzolisation and accumulation of undecomposed organic matter under marshy conditions contribute to soil acidity.

2.0 Production constrains of acid soils

A. Related to soil physical properties

- Leaching of bases, fine earth and organic matter
- Coarse texture soils (high macro pore)
- Low organic matter, weak soil structure
- High infiltration and permeability rate,
- Low moisture holding capacity
- Formation of soil crust, particularly in red and laterite soils (seed germination is affected)
- More susceptible to drought, dry spells
- Poor drainage of peat, marshy and acid sulphate soils

B. Related to soil chemical properties

- Low P-availability and high P-fixation capacity
- Toxicity of Fe and Mn (Al in some cases)
- Low organic matter status of lateritic and red soils
- Deficiency of secondary nutrients (Ca, Mg), and micronutrients (Mo, B and Zn)
- Leaching losses of nutrients are high
- Nutrient imbalance, low cation exchange capacity
- Dominance of kaolinite and sesqui-oxides clay fraction (low water holding capacity)
- Low level of base saturation percentage

3.0 Acid soils management – Integrated approach

Acid soils particularly acidic upland is the main area of production of pulses, oilseeds and coarse cereals. Liming increases the soil pH, improves availability of plant nutrients and crop growth, increases nutrient uptake, stimulates biological activity, decreases extractable Al<sup>3+</sup> and reduces toxicity of some elements. Study revealed that liming the soils below pH 4.5 is not economical, thus integrated
approaches (Combination of chemical, engineering and agronomic measures) are required to enhance the productivity of acid soils under such a situation.

A. Chemical measures: (preferably soil with pH > 4.5)

Common problems in acid soils in respect of chemical properties could be managed simply by soil amelioration with liming materials which improves pH, base status, CEC, inactivates Al, Fe, and Mn in soil solution, reduce acidity and P fixation in soil remarkably.

B. Engineering measures:
- Ridge and furrow tillage, conservation tillage
- Contour and strip cropping, bench terracing
- Raising of field bunds for in-situ rain water harvesting
- Runoff water harvesting and recycling
- Compaction of surface layers with heavy rollers/ heavy tractors
- Chiesseling of soils with surface compact layers to a depth of 30-45 cm at 60-120 cm interval

C. Agronomic measures:
- Making aggregate stability by application of compost, paddy straw, green manure and inclusion of legumes in rotation
- Crust formation can be controlled by straw mulch on seed lines, incorporation of powdered groundnut shell, paddy husks two weeks before seeding
- Addition of tank silt and clay to increase water retentivity.
- Decrease in bulk density, appreciable rise in % of pore space, improvement in soil structure, moisture holding capacity & hydraulic conductivity can be done by application of organic matter, legumes in the cropping system etc.
- Adoption of suitable crops/cropping system along with scientific package of practices

Relative response of crops to liming:

High response group: Pigeonpea, soybeam, cotton
Medium response group: Groundnut, pea, gram, lentil, maize, wheat, sorghum
Low response group: Barley, upland paddy

Table-1: Identified Crop varieties relatively tolerant under acidic soil (pH < 5.5) conditions

<table>
<thead>
<tr>
<th>State</th>
<th>Crop</th>
<th>Varieties Identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assam</td>
<td>Rapeseed</td>
<td>Varuna, Sonmukhi</td>
</tr>
<tr>
<td></td>
<td>Summer green gram</td>
<td>K851, Sonmngu</td>
</tr>
<tr>
<td>Kerala</td>
<td>Vegetable Cowpea</td>
<td>Bhagyalakshmi</td>
</tr>
<tr>
<td></td>
<td>Cowpea(bush type)</td>
<td>V-16</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>French bean</td>
<td>HUR-15</td>
</tr>
<tr>
<td>Jharkhand</td>
<td>Blackgram</td>
<td>KU-301</td>
</tr>
<tr>
<td>Orissa</td>
<td>Groundnut</td>
<td>Smruti</td>
</tr>
<tr>
<td></td>
<td>Pigeon pea</td>
<td>UPAS.120</td>
</tr>
<tr>
<td>Himachal Pradesh</td>
<td>Soybean</td>
<td>Haraosya</td>
</tr>
<tr>
<td></td>
<td>Brassica</td>
<td>HPN-3, TERI-9803</td>
</tr>
</tbody>
</table>
5.0 Choice of liming materials

Limestone is the most common liming material used to ameliorate acid soil but small and marginal farmers of eastern India could not afford to purchase lime in the form of pure CaCO$_3$ or MgCO$_3$ because of their relatively high cost. Alternative cheap sources of liming materials like paper mill sludge (PMS) from bi-products of paper mill, basic slag from steel industry that contains CaCO$_3$ can be used to ameliorate acid soil but the quantity of PMS required depends on the content of Ca and Mg in the sludge, soil type, crop species and cultivars. Liming material must be locally available; properly grinded and should have high neutralizing value and low cost for use by small and marginal farmers. Orissa has vast resources of limestone occurring in three distinct geological settings, namely (i) Gangpur group, (ii) Vindhya and (iii) Eastern Ghat, whereas dolomite is mostly confined to (i) Gangpur and (ii) Vindhyan Groups. Large resources of lime stone are also available in Arunachal Pradesh, Manipur, Assam, Meghalaya and Nagaland. Jharkhand.

Acid soil management through low cost liming materials in Orissa – A Success Story

In Orissa, out of 15.8 mha geographical area, 12.8 mha area (about 80%) is acidic (pH: 5.0-6.5). Rough estimates show that in Orissa about 12 percent of acid soils are strongly acidic (pH<5.0), 48 percent moderately acidic (pH 5.0-5.5), and 40 percent mildly acidic (pH 5.5-6.5). Agriculturally important districts in Orissa having acid soils pH < 5.5 are Mayurbhanj (80%), Denkanal (82%), Angul (80%), Phulbani (74%), Sundargarh (63%) Cuttack (95%), Kendrapada, Jagatsinghpur, Jaipur, Angul, Koraput (33%), Nawrangpur, Khurda, Nayagarh, Puri. Alternative cheap sources of liming materials like paper mill sludge (PMS) from bi-products of paper mill, basic slag from steel industry that contains CaCO$_3$, Ferrochrome powder – trade name “Bhusakti”, TISCO slag powder – trade name “IRL clay” are largely available in Orissa which can be used to reclaim acid soils. Recognizing the importance of reclamation of acid soils using low cost liming materials, a project on “Agricultural diversification for enhancing productivity of acidic uplands of eastern India”, sponsored by Technology Information Forecasting and Assessment Council (TIFAC) was executed by Directorate of Water Management, Bhubaneswar from 2006-07 to 2009-10 in representative acid soil areas of Orissa i.e. Rautrapur village of Durgadevi Panchayat of Remuna Block, Balasore district and Bhimda village of Badasahi block of Mayurbhanj district. In addition to soil amelioration with low cost paper mill sludge of nearby paper mill factory, efforts were also made to diversify cropping system (maize, groundnut, sunflower, blackgam / maize, groundnut, sunflower, sesame and rice) and to conserve rainwater for its recycling to ensure higher and stable agricultural productivity of acid affected soils. The productivity, net returns and rainwater use efficiency of non-rice crops were compared with that of rice crop.

The chemical and physical properties of the paper mill sludge vary according to nature of manufacturing processes. In this study proprieties of Emami paper mill, Balasore were analysed in the laboratory of DWM, Bhubaneswar which had pH (1:2.5): 8.23 ; EC : 0.20 dsm$^{-1}$ ; Average Ca and Mg : 7.2 meq/100g soil ; CaCO$_3$ equivalent : 30.00% ; Water holding capacity : 119.0% ; Organic carbon : 25.00% ; Nitrogen (Total) : 0.87% ; Phosphorous :
Study revealed that after ameliorating soil with PMS @ 50% lime requirement (LR), and 100% NPK, higher net returns were obtained from rainfed acidic upland during kharif season. The net returns (Based on analysis in 2009-2010) of Rs 13750/- to 14,230/-, Rs 14560/- to 14590/-, Rs 17740/- to 23760/-, Rs 15080/- to 21380/- per ha were obtained from groundnut, maize, sunflower and blackgram respectively, but much lower net returns were obtained from rice (Rs 4160/- to 8850/). Without application of PMS in control plot, Rs 360/- to 1760/-, Rs 15080/- to 21380/- per ha were obtained from groundnut, maize, sunflower and blackgram respectively, but much lower net returns were obtained from rice (Rs 4160/- to 8850/-). Without application of PMS in control plot, Rs 360/- to 1760/-, Rs 15080/- to 21380/- per ha were obtained from rice, groundnut, maize, sunflower, blackgram, respectively.

Application of PMS in the experimental field

Study revealed that after ameliorating soil with PMS @ 50% lime requirement (LR), and 100% NPK, higher net returns were obtained from rainfed acidic upland during kharif season. The net returns (Based on analysis in 2009-2010) of Rs 13750/- to 14,230/-, Rs 14560/- to 14590/-, Rs 17740/- to 23760/-, Rs 15080/- to 21380/- per ha were obtained from groundnut, maize, sunflower and blackgram respectively, but much lower net returns were obtained from rice (Rs 4160/- to 8850/). Without application of PMS in control plot, Rs 360/- to 1760/-, Rs 15080/- to 21380/- per ha were obtained from rice, groundnut, maize, sunflower, blackgram, respectively.

During rabi season also higher crop productivity, net returns and water use efficiency were obtained with PMS @50% LR and 100% NPK. Among the rabi crops studied, lowest rice equivalent yield (43.6 to 45.1 q/ha) was obtained in sesamum and higher (59.5 to 66.7 q/ha) was obtained from sunflower. Highest net returns per hector (Rs 26650/- to 31690/-) were also obtained from sunflower crop whereas lower net returns were obtained from winter rice under that treatment. Without PMS treatment, the net returns per hector were much lower i.e. Rs 6780/- to 7760/-, Rs 9860/- to 10970/-, Rs 8950/- to 13710/-, 1670/- to 3210/-, Rs 6670/- to 9610/- from groundnut, maize, sunflower, sesamum, and rice, respectively in different study years.
In groundnut average over years, the lowest grain yield (1063 to 1126 kg ha⁻¹) was obtained under 0% LR whereas, the highest grain yield of 1493 to 1618 kg ha⁻¹ was obtained under 60% LR though it was statistically non-significant from the yield values obtained at 50% LR.

The dose of applied liming materials depends on the CaCO₃ equivalent of the liming materials, soil texture and its cation exchange capacity (CEC), existing soil pH and desired soil pH to bring after soil amelioration. The requirement of lime (kg/ha) to reclaim acid soil from different levels of pH to raise soil pH to 6.5 are given in Table-2 below. Since application of full lime requirements is very high and may not affordable by farmers, 20-25% of full lime has been recommended to apply every year in plough layer. The cost of cultivation to grow annual crops in 1 hectare of land after soil amelioration with Paper Mill Sludge is estimated as about Rs. 21,000/-, Rs. 18,000/- and Rs. 13,000/ for the soils with pH range of 4.5 to 5.0, 5.1 to 5.0 and 5.6 to 6.0, respectively.
Table-2: Requirement of lime (t/ha) to reclaim acid soil (lime required to raise pH to 6.5)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>pH Range</th>
<th>Sandy</th>
<th>Sandy loam</th>
<th>Loam</th>
<th>Silt loam</th>
<th>Clay &amp; loamy clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>4.5 to 5.0 (For pure CaCo3)</td>
<td>4.25</td>
<td>7.25</td>
<td>10.75</td>
<td>15.00</td>
<td>20.00</td>
</tr>
<tr>
<td></td>
<td>Equivalent quantity of Emmami PMS</td>
<td>14.1</td>
<td>23.9</td>
<td>35.4</td>
<td>49.5</td>
<td>66.6</td>
</tr>
<tr>
<td>2.</td>
<td>5.1 to 5.5 (Pure CaCo3)</td>
<td>2.5</td>
<td>4.25</td>
<td>6.25</td>
<td>8.50</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>Equivalent quantity of Emmami PMS</td>
<td>8.25</td>
<td>14.02</td>
<td>20.6</td>
<td>28.1</td>
<td>37.3</td>
</tr>
<tr>
<td>3.</td>
<td>5.6 to 6.0 (pure CaCo3)</td>
<td>1.0</td>
<td>1.8</td>
<td>2.5</td>
<td>3.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Equivalent quantity of Emmami PMS</td>
<td>3.3</td>
<td>7.6</td>
<td>8.3</td>
<td>11.6</td>
<td>16.5</td>
</tr>
</tbody>
</table>

NB: Soil having pH less than 4.5 may not be treated. PMS = Paper Mill Sludge

Rainwater harvesting and its multiple uses to develop pond based farming system

Pond based farming system was designed and implemented in the study villages viz; Routrapur, Balasore and Bhimda, Mayurbhanj. The rainwater was harvested into the farm ponds and utilized in multiple ways like growing of crops, on dyke horticulture, fisheries. Study revealed that after adopting the pond based farming system in upland acid soil net returns of Rs. 35000/- to Rs. 50,000/ ha were obtained, which was 3-4 times higher than that of earlier.

Growing of Banana crop on the pond bund

Harvested rainwater in the farm pond

Rearing of fish with harvested rainwater

Growing of rabi crops utilizing supplemental irrigations from harvested rainwater
Contingency crop planning

The contingency crop planning was implemented in farmer's field when main crops during kharif/ rabi season were damaged. That land was utilized by growing mustard and horsegram during pre-rabi period (October to November) utilizing residual soil moisture, supplemental irrigation and papermill sludge. The grain yield of 1.15 to 1.25 t/ha and 1.0 to 1.2 t/ha was obtained in mustard and horsegram crops, respectively from the recommended technologies of DWM, Bhubaneswar.

Community Mobilization, Technology Demonstration & Training

- Technology of crop diversification, acid soil management and pond based integrated farming system were disseminated through National level Model training Course on 'Farm Level water harvesting techniques for sustainable agriculture and alleviating poverty', sponsored by Directorate of Extension, Ministry of Agriculture, GoI. Organized one week training programme on “Scaling up Water Productivity in Agriculture for livelihoods”, sponsored by Ministry of Agriculture, Govt. of India at Rautrapur, Balasore from 16th to 22nd December, 2008 and One day field training was organized on 6.11.2007 on 'Enhancing productivity of upland acid soils' at Mayurbhanj, Orissa, for community mobilization to adopt the technology.

- Technology of crop diversification, acid soil management and pond based integrated farming system were also disseminated through Farmers' Participatory Action Research Programme (FPARP) in seven districts of Orissa.

- Efforts were made to disseminate technologies in different exhibitions, organized by different government and non-government organizations.

- Rainwater harvesting system and agricultural diversification model (on-dyke horticulture, fisheries, cultivation of diversified field crops, short term fruits, floriculture) with harvested rainwater were popularized. The detailed cost estimates, investment, man days generation, production potential, potential gross income generation per year, potential man days generation due to asset created through pond based integrated farming system were computed and technology can be included under 'Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) for implementing in watersheds of eastern Indian states
8th October, 2010, The Indian Express

MANAGING ACIDIC SOIL

Paper mill waste can enhance soil productivity

Express News Service

Bhubaneswar, Oct 8: Industrial byproducts like paper mill sludge and press mud can be used scientifically for soil health and productivity if taken up on a large scale as a part of capacity building and technology dissemination programme organized at project sites of Balasore and Mayurbhanj, Odisha.

Agricultural scientist Vimlendra Singh from Water Technology Centre for Eastern Region (WTCE), chairman of the Indian Council of Agricultural Research, said that the sludge and press mud can be used as an amendment to the soil to improve its fertility and productivity. The sludge and press mud can be used as a source of nitrogen, phosphorus, and potassium, which are essential for plant growth and development.

The sludge and press mud can be used as a substitute for chemical fertilizers, which are expensive and harmful to the environment. The sludge and press mud can be used as a natural fertilizer, which is free of chemicals and is environmentally friendly.

13th August, 2007, The Indian Express

They made fertile patch of green out of barren land

Express News Service

Bhubaneswar, Aug 13: For the villagers of Bhubaneswar, the transformation of the live stock, dry grass, shearing, and the barren land into a fertile patch of green, was a lifetime experience. For them, they had never thought in their dreams that they could live in a place with such greenery and fertility.

Thanks to the initiatives taken by the scientists of the Water Technology Centre for Eastern Region (WTCE), the soil was transformed from a barren land into a fertile patch of green. They did this by following the principles of sustainable agriculture.

The villagers were not only beneficiaries of the project, but they were also partners in the project. They were involved in the planning and implementation of the project from the very beginning.

They were trained in sustainable agriculture practices, and were provided with the necessary tools and equipment to cultivate their land. They were also provided with the necessary financial assistance to start their own small businesses.

The villagers were also provided with the necessary training in soil testing and land management. They were taught how to test their soil and how to improve its fertility and productivity.

The villagers were also provided with the necessary training in crop rotation and intercropping. They were taught how to diversify their crops and how to use the available resources in the most efficient way.

The villagers were also provided with the necessary training in water management. They were taught how to conserve and use water in the most efficient way.

The villagers were also provided with the necessary training in pest management. They were taught how to control pests and diseases effectively.

The villagers were also provided with the necessary training in marketing and business skills. They were taught how to sell their products and how to run their businesses efficiently.

The villagers were also provided with the necessary training in computer and management skills. They were taught how to use computers and how to manage their businesses effectively.

The villagers were also provided with the necessary training in financial management. They were taught how to keep track of their finances and how to manage their money effectively.

The villagers were also provided with the necessary training in health and safety. They were taught how to protect themselves and their families from the risks of work and illness.

The villagers were also provided with the necessary training in nutrition and health. They were taught how to eat well and how to live a healthy life.

The villagers were also provided with the necessary training in social and cultural issues. They were taught how to respect and appreciate the diversity of their community.

The villagers were also provided with the necessary training in environmental issues. They were taught how to protect and conserve the natural resources of their community.

The villagers were also provided with the necessary training in legal issues. They were taught how to protect their rights and how to fight for their interests.

The villagers were also provided with the necessary training in community development. They were taught how to work together and how to improve the quality of life in their community.

The villagers were also provided with the necessary training in community management. They were taught how to manage their community and how to make decisions.

The villagers were also provided with the necessary training in community leadership. They were taught how to lead and how to make a difference.

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