11. Integrated Nutrient Management Sustainable for Land Use in Watersheds

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Abstract

Apart from water shortage, the productivity in rain-fed systems is also constrained by low soil fertility. The soils in the SAT regions generally have low organic matter and nutrient reserves. Extensive survey of the farmers' fields in the SAT regions of India revealed that the deficiencies of sulfur, boron and zinc are very widespread and in most cases 80-100% farmers' fields were found critically deficient in these nutrients. This paper underscores the need to integrate soil and water conserving practices with balanced nutrition of crops by adopting INM.

Keywords: Community participation, watersheds, knowledge sharing, entry point activity.

Introduction

Increasing needs of food, feed, fuel and fiber for the ever increasing population in the semi-arid tropical (SAT) regions of the developing world is putting pressure on the rain-fed areas to make greater contribution from the vast area under dryland agriculture. The smallholder farmers rely on the dryland subsistence productivity for their livelihood and the productivity of dryland systems remains low due to low and erratic distribution of rainfall coupled with low to negligible inputs of nutrients. Maintenance of soil organic matter is a challenge, because of competing uses of organic materials and crop residues. Organic matter is not just the source of nutrients, but is essential for preserving soil's physical, chemical and biological integrity for the soil to perform upto its productivity, health and environment-related functions on a continuing basis. With little investment in the management of soils, large area under dryland agriculture is in various stages of physical, chemical and biological degradation. Thus combating land degradation and increasing productivity of drylands is a major challenge for conserving the integrity of dryland soils (Singh et al. 2004). To achieve sustainable improvement in dryland productivity, there is need to have a holistic approach in which soil and water conservation practices are implemented along with integrated nutrient management strategy (INM) (Wani et al. 2003, 2005).

Fertility–Related Constraints

Diagnosis of Soil Fertility Problems for Enhancing Crop Production

Farm holdings in the SAT are not only distinct in terms of size, shape and location on a toposequence but also vary widely for the cropping patterns, quality and quantity of nutrients used for cop production. Major constraint is the timely availability of knowledge and right information about soil health for the farmers. As described below, farmers do not know what is ailing their farm in general. It is of utmost importance to establish soil quality analytical laboratories in each district of a state to provide timely and correct information to the farmers relating to the diagnosis of soil fertility constraints and physical and biological conditions.

Apart from water shortage, the productivity in rain-fed systems is also constrained by low soil fertility. The soils in the SAT regions generally have low organic matter and nutrient reserves. Soil erosion removes the top soil layer, which not only results in the loss of soil but also in loss of organic matter and plant nutrients, which largely are stored in the top soil layer (Wani et al. 2003). Among the major nutrients, nitrogen is universally deficient and phosphorus deficiency ranks only next to nitrogen in most of the SAT soils. Our work has also shown that potassium reserves in the SAT soils are generally adequate (Rego et al. 2007). Most of the SAT soils have low to moderate phosphorus absorption capacity and most of the rain-fed systems require low to moderate rates of phosphorus applications to meet their phosphorus requirements, considering residual benefits also (Sahrawat et al. 1995; Sahrawat 1999, 2000). Many of the farmers' fields in the SAT regions of India are deficient in secondary and micronutrients. Our extensive survey of the farmers' fields in the SAT regions of India revealed that the deficiencies of sulfur, boron and zinc are very widespread and in most cases 80-100% farmers' fields were found critically deficient in these nutrients (Table 1) (Rego et al. 2007).

To enhance and sustain SAT agricultural productivity and food security there is a need to adopt (INM) strategy.

Table 1. Chemical characteristics of 924 soil samples collected from farmers' fields in three districts of Andhra Pradesh, India, 2002-04

District	No of fields		pH	Organic C	Total N	Olsen -P	Exch. K	Extractable nutrient elements (mg kg^{-1})		
				g kg-1	--------mg kg^{-1}-------			S	B	Zn
Nalgonda	256	Range	5.7-9.2	1.2–13.6	144-947	0.7-37.6	34-784	1.4-93.0	0.02-1.48	0.08-16.00
		Mean	7.7	4.0	410	8.5	135	7.00	0.26	0.73
		% deficient[a]						86	93	73
Mahabu-bnagar	359	Range	5.5-9.1	0.8–12.0	123-783	0.7-61.0	25-487	1.1-44.0	0.02-1.62	0.12-35.60
		Mean	7.1	3.6	342	9.1	117	11.5	0.22	1.34
		% deficient						73	94	62
Kurnool	309	Range	5.6-9.7	0.9–10.6	26-966	0.4-36.4	33-508	1.3-68.2	0.04-1.64	0.08-4.92
		Mean	7.8	3.4	295	7.9	142	5.6	0.34	0.42
		% deficient						88	83	94

[a]The critical limits in the soil used : 8-10 mg kg^{-1} for calcium chloride extractable S; 0.58 mg kg^{-1} for hot water extractable B;0.75 mg kg^{-1} for DTPA extractable Zn.

Strategy for Productivity Enhancement and Fertility Maintenance

INM Strategy

The INM strategy includes maintenance or adjustment of soil fertility and plant nutrient supply to sustain the desired level of crop productivity using all available sources of nutrients eg, soil organic matter, soil reserves, biological nitrogen fixation (BNF), organic manures, composts non-toxic organic wastes mineral fertilizers, and nutrients supplied via precipitation and irrigation water. INM is a holistic system approach focusing on the cropping system rather than on individual crop. INM also focuses on the farming system rather than on individual field. It does not preclude the use of renewable nutrient sources such as BNF and organic manures and minimal use of mineral fertilizers.

Strategies to Manage Soil Organic Matter

Organic matter is not just the reservoir of plant nutrients; organic matter also favorably influences physical and biological properties, productivity of soils. High prevailing temperatures in the tropics coupled with low net primary productivity in the dry regions, results in low organic matter reserves in the SAT soils.

Organic Inputs for Nutrient Management

Organic manures are of two types: bulky farm yard manure (FYM), composts (rural and town), crop residues; *in-situ* green manuring and *concentrated-* oilcakes, poultry manure, slaughter house waste, etc. FYM is the most commonly used organic manure particularly for high-value crops. It is prepared from animal-shed wastes and crop residues including stover and contains 0.5-1.0%N, 0.2-0.3 and 0.5-1.0% P and 0.03-0.35% K. Crops residues can be recycled by composting, and its nutrient enrichment through organic/inorganic amendments by using rock phosphate, pyrites**,** microbial cultures**,** vermicompositing, mulching and direct incorporation. Based on N content, organic manures are less efficient than mineral fertilizers; however combined use of these nutrient sources is superior than using mineral fertilizer or organic manure alone. A combination of crop residue restitution (based on the availability), fallowing or green manuring can be used to maintain organic matter levels in the soil.

In farms as well as in homes large quantities of organic wastes are generated regularly. Besides agricultural wastes, large quantities of domestic wastes are generated in cities and rural areas which are wasted by burning or used as land fillings. These valuable nutrients in residues can be effectively used for increasing the agricultural productivity using earthworms to convert the residues into valuable source of plant nutrients. The chemical changes in the degradation of organic matter occur through enzymatic digestion and enrichment materials. The burrowing and channeling habits of earthworms result in better soil aeration, drainage and structure. The dominance of earthworms innate capacity to improve soil fertility and their ability to multiply rapidly has led to the development of vermicomposting (Table 2). The process of preparing valuable manure from all kinds of organic residues with the help of earthworms is called "vermicomposting" and this manure is called vermicompost.

Types of Organic Materials

Vermicompost can be prepared from all types of organic residues such as agricultural residues, sericultural residues, animal manures, dairy and poultry wastes, food industry wastes, municipal solid wastes, biogas-sludge, and bagasse from sugarcane factories.

Vermicompost Preparation

Vermicompost can be prepared by different methods in shaded areas:

(i) on the floor in a heap; (ii) in pits (up to 1 m depth); (iii) in an enclosure with a wall (1 m height) constructed with soil and rocks or brick material or cement; and (iv) in cement rings. The procedure for preparation of vermicompost is similar for all the methods (Figure 1).

Figure1. Farm women learning (vermicompost preparation).

Step-Wise Procedure

- Cover the bottom portion of a cement ring with a polythene sheet.
- Spread a layer (15–20 cm thick) of organic waste material on the sheet.
- Sprinkle rock phosphate on this layer.
- Prepare cowdung slurry.
- Sprinkle powdered the slurry as a layer.
- Fill the ring completely with the materials in layers.
- Paste the top portion of the ring with cowdung or soil.
- Allow the material to decompose for 20 days.
- After 20 days, release selected earthworms (non-burrowing types eg., Eisonia spp, Eudrilus spp) through the cracks.
- Cover the ring with wire mesh or gunny bags to prevent birds from picking the earthworms.
- Sprinkle water on the surface of the compositing material at 3-day intervals to maintain adequate moisture and body temperature of the earthworms.
- Check compost after about 2 months:
  - vermicompost is ready in 2–2½ months, and
  - it is black and light, and has no smell.
- When the compost is ready, remove from the ring and heap as a cone.
- Leave the heap undisturbed for 2 to 3 hours to allow the earthworms to move down the heap slowly.
- Separate the upper portion of the heap.

- Sieve the lower portion of the heap to separate the earthworms, which can be used again for preparation of vermicompost.
- Pack the compost in bags and store these in a cool place.

Repeat Process

About 20 days before removing the compost from cement rings, place the organic waste, rock phosphate and cowdung slurry in layers in another set of rings. Follow the step-wise procedure and use the earthworms separated from the compost as mentioned above.

Precautions

- Use only plant materials such as vegetable peelings, leaves, or grass.
- Remove glass, metal, and plastic materials from the organic material.
- Protect against birds by covering mesh on the rings.
- Sprinkle the water intermittently and maintain adequate moisture.
- Prepare compost under shade to protect from sun and rain.
- Avoid pesticide/toxic chemicals

Usage

Vermicompost can be used for agricultural, horticultural, ornamental, and vegetable crops and any stage of the crop. Vermicompost is a rich source of major and micro plant nutrients (Table 2) and can be applied in varying doses in the field.

Table 2. Nutrient composition of vermicompost

Nutrient element	Vermicompost (%)
Organic carbon	9.8–13.4
Nitrogen	0.51–1.61
Phosphorus	0.19–1.02
Potassium	0.5–0.73
Calcium	1.18–7.61
Magnesium	0.093–0.568
Sodium	0.058–0.158
Zinc	0.0042–0.110
Copper	0.0026–0.0048
Iron	0.2050–1.3313
Manganese	0.0105–0.2038

Enriched Compost Production Technology

Most of the Indian soils are deficient in Phosphorus. Also, yearly removal of P is more than its addition through P fertilizers during continuous and intensive cropping. Bio-solids produced in cities, agro-industries and at farms normally have low nutrient value, particularly of P content. Compost production from these bio-degradable wastes is presently not an economically viable proposition. The traditional technology of composting, if improved in terms of nutrients content, may help in arresting trends of nutrient depletion to a greater extent. Further, the use of mineral additives such as rock phosphate and pyrites during composting has been found beneficial. A phosphocompost/N-enriched phosphocompost technology has, thus, been developed using phosphate solubilizing microorganisms, namely, *Aspergillus awamori*, *Pseudomonas straita* and *Bacillus megaterium*; phosphate rock, pyrite and bio-solids to increase the manurial value compared to ordinary FYM and compost (Misra et al. 2003).

Method

- For the production of one ton of phosphocompost, materials such as 1900 kg organic/vegetable wastes/straw, 200 kg cow-dung (dry weight basis) and 250 kg phosphate rock (18% P_2O_5) are used.
- Prepare a base of the heap out of hard, woody materials such as sticks, bamboo sticks etc., This base should be 15 cm thick and 3 m width and 3 m length depending upon the quantity of materials to be composted.
- Place bio-solids over the base made above. The layer should be around 30 cm to10 cm thick.
- Sprinkle slurry prepared by mixing cow dung and rock phosphate over the crop residues to moisten the material.
- Make another layer of crop residue and moisten it with slurry.
- Continue with alternate layer of crop residue (30 cm) and slurry until the heap is 1.5 m high. Reduce the area of each layer so that the heap tapers by about 0.5 m high. Reduce the area of each layer so that the heap tapers by about 0.5 m at the top. Add water to the heap so that moisture remains about 60 to 70%.
- Cover the heap with soil or polythene and mix the material after 15 days. Give two turnings after 30 and 45 days. Add water at each turning to maintain the moisture content about 60-70%.
- The compost becomes ready for field application within 90-100 days period.

Nutritional Quality

- The phosphocompost contains 2-3.5% P and 17-18 C:N ratio.

Table 2. Nutrient composition of manure and phosphocompost

Manure	Total N (%)	Total P (%)	C:N ratio
FYM	0.5-0.8	0.32-0.55	22.0-25.0
Ordinary Compost	0.6-0.8	0.55-0.60	22.0-25.0
Phospho-compost	1.2-1.4	2.00-3.50	17.0-18.0

Yield Advantage

Field experiments conducted across different states under AICRP on microbiological decomposition under irrigated and rain-fed situations revealed that use of phosphocompost can fulfill the P requirement of various crops and farmers can do away with the use of phosphatic fertilizers. In view of the multi-nutrient deficiency of Indian soils, an effort has been made to enrich manurial value particularly sulphur and N content of the compost.

- To prepare N-enriched phospho-compost, nitrogen as urea at 0.5-1% (w/w), rock phosphate (12.5% w/w) and pyrite at10% (w/w) are added into the composting mixture.
- The N-enriched phospho-compost contains 1.4-1.6% N and 15-20 C:N ratio.
- Field testing of the N-enriched phospho-compost revealed that when 25% of fertilizer NPK was substituted by Nitro-Phospho-Sulpho-Compost yield advantage over NPK fertilizer was 11.5% in soybean and 2.5% in sorghum. This had also significant residual effect on yield of succeeding wheat crop.

In-situ Generation of Organic Matter

Short supply of organic manures and competitive uses of farm residues as feed and fuel make it difficult to apply these materials to soil at desired rates. Green leaf manuring is one of the important farming practices for increasing organic matter content in the soil. Green leaf manure plants such as *Susbania, Sunnhemp, Glyricidia, Cassia, Leucaena* can play an important role in tropical farming systems for increasing the soil fertility. Growing *Glyricidia* plants on farm bunds serves dual purpose of producing green leaf manure, rich in N, under field conditions and also helps in conserving soil through reduced soil erosion (Figure 2).

Figure 2. Glyricidia plants grown on border of chickpea field under rain-fed situation in India.

Characteristics of Glyricidia

- *Glyricidia* is a *woody,* green leaf manure tree about 12 m in height.
- The foliage can be used as green manure (natural fertilizer).
- Glyricidia is a root-nodulating N_2-fixing multipurpose legume.
- It grows fast and is tolerant to pruning.
- It can thrive in dry, moist, acidic soils or even poor degraded, infertile soils under rain-fed conditions.
- The leaves contain nutrients: N (2.4%), phosphorus (P) (0.2%), potash (K) (1.8%), Calcium (Ca), and Magnesium (Mg).
- *Glyricidia* adds plant nutrients and organic matter to the soil and increases crop productivity on infertile and degraded soils.
- *Glyricidia* can be propagated through stem cuttings or seed.

Glyricidia cuttings are taken from stems of at least one-year-old plants from mature branches 2–6 cm in diameter and 30–100 cm in length, which are brownish-green in bark color. It is normally cut obliquely at both ends, discarding the younger tips and base inserted 20-50 cm into the soil. The cuttings are planted on bunds in the rainy season, immediately after cutting from the stems. The hedges can be periodically pruned to provide fodder, green manure, firewood or stakes for new fences. Alternatively, Glyricidia seeds are soaked in water for 8 – 10 hours preferably overnight and are sown in small polythene bags filled with soil, and watered regularly. Generally, 3 - to 4-months old seedlings can be planted on bunds in the rainy season

Pruning

One year after planting, harvesting of the green biomass can be started by lopping the plants at 75 cm above the ground. For good management, plants should be pruned at appropriate times. Pruning should be done at least thrice during the year; ie, June (before sowing of the rainy season crop), in November (before sowing