Chapter

Packages of Organic Nutrient Management as Soil Policy for Upgrading Cropping System to Restore Soil Productivity

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Abstract

The indigenous farming systems are, by and large, organically practiced. Organic farming systems facilitate the buildup of soil organic matter, reducing risk of erosion and runoff and enhancing nutrient storehouse in soils for plants. Rapid developments in organic farming promotion necessitated continuous flow of technology to meet day-to-day challenges. Farmyard manure (FYM), compost, and green manure are the most important and widely used bulky organic manures. Manuring with different short-duration legumes is suitable for maintenance of soil quality in terms of adding nitrogen to soil. Sustainable quantity of potassium can be maintained by vegetative mulching with crop residues. The use of balanced dosages of mixed compost at 5–10 t/ha along with 2 t/ha dolomite increases yield of maize, rice, mustard, and soybean. This article briefly describes about the integrated organic nutrient management as soil policy for upgrading cropping system to restore soil productivity.

Keywords: organic farming, balanced dose, soil, policy, manure, cropping system

1. Introduction

Sikkim enjoys a wide range of climate, physiographic, geology, and vegetation that influence formation of different kinds of soils. Hills of Sikkim mainly consist of gneissose and half-schistose rocks, producing generally poor and shallow brown soils [1, 2]. The soil is coarse, with large concentrations of iron oxide, and ranges from neutral to acidic, making it lacking in mineral nutrients. This type of soil tends to support evergreen and deciduous forests [3]. Rock consists of phyllites and schists, which is much younger in age and is highly susceptible to weathering and erosion [4–8]. This combined with the state's heavy rainfall causes extensive soil erosion and the loss of soil nutrients through leaching. Soils of Sikkim belong to 3 orders, 7 suborders, 12 great groups, and 26 subgroups. It is observed that inceptisols are dominant (42.84%) followed by entisols and mollisols occupying 42.52 and 14.64%, respectively. Percentage area under Zn deficiency (<0.6 mg kg^{-1}) in Sikkim is 15.69% (202.35 sq. km) of the geographic area having highest Zn deficiency in South Sikkim district (82.07 sq. km, 19.1% of TGAD) followed by East (56.84 sq. km, 13.3% of TGAD), West (48.91 sq. km, 15.7 of TGAD), and North (14.53 sq. km, 11.8% of TGAD). Percentage area under Mn deficiency (<3.5 mg kg^{-1}) in Sikkim is 10.16% (131.02 sq. km) of the geographic area having highest Mn deficiency in South Sikkim (48.72 sq. km, 11.3 of TGAD) followed by East (34.52 sq. km, 8.1% of TGAD), North (28.82 sq. km, 23.13% of TGAD), and West (18.96 sq. km, 6.1% of TGAD). Total degraded area in Sikkim is 60,000 ha (9% of TGA), of which West Sikkim is highly degraded, followed by South Sikkim and North Sikkim [9–13]. Erosional hazard has affected about 2000 ha (0.28% of TGA of the state). South Sikkim is the worst affected district, followed by West Sikkim and North Sikkim [14, 15]. Sikkim being hilly state practicing terraced agriculture on an extensive scale could successfully control soil erosion [16].

2. Integrated organic nutrient management practices

The major challenge in organic agriculture is the availability of huge quantities of organic inputs for satisfying the farm demand. The use of animal excreta-based manure alone is not sufficient for meeting the nutrient needs of the crops. It is, therefore, necessary to utilize all the sources available on and off farm effectively [17]. The resource components available for nutrient management in organic horticulture are the following: farmyard manure (FYM), crop residue, weed biomass, green manures, biofertilizers, composts/phospho-compost, vermicomposting, oil cakes, mulching/cover crop, liquid manures, biodynamic preparation, botanicals, legumes in cropping sequence, and certified commercial products. Maintenance of soil fertility may be achieved through organic matter recycling, enrichment of compost, vermicomposting, animal manures, urine, farmyard manure, litter composting, use of botanicals, green manuring, etc. Biofertilizers like *Azolla*, *Azospirillum*, *Azotobacter*, *Rhizobium* culture, PSB, etc. can be used. Sawdust from untreated wood, calcified seaweed, limestone, gypsum, chalk, magnesium rock, and rock phosphate can be used [18]. Various sprays like vermiwash, liquid manure, etc. can be used in crops for nourishing the soil and plant. Farmyard manure, compost, and green manure are the most important and widely used bulky organic manures. Partially decomposed FYM has to be applied 3–4 weeks before sowing, while well-decomposed FYM should be applied immediately before sowing [19]. Manuring with different short-duration legumes is suitable for maintenance of soil quality in terms of adding nitrogen to soil. Nitrogen addition by sun hemp (150–200 kg/ha N) and dhaincha (125–175 kg/ha N) is highly beneficial for the succeeding crops and even for the subsequent crops too. Crop residue can also produce 2.47 kg N, 0.53 kg P, and 8.87 kg K per ha. Edible oil cakes of mustard and nonedible oil cakes from neem, karanj, and castor can serve the dual purpose of manure and bio-pest control [20–25]. Vermicompost can be used for a wide variety of horticultural, ornamental, and vegetable crops at any stage. Generally vermicompost is applied at 3–5 t/ha in row zones for field crops, whereas, for fruit crops, it is preferred to use the same mixing with equal amount of FYM in periodic interval. The general recommendation dose of vermicompost is 6–8 t/ha for field crop and 3–5 t/ha for subtropical fruits [26, 27]. In case of soil application, desired strain of biofertilizer is normally mixed with 20 times well-decomposed FYM to maintain uniformity of mixture and applied in furrows. However, for seedling treatments, biofertilizer slurry is made (1:10 ratio) in water, and roots are emerged in suspension for about 30 minutes. For cereals like, maize, baby corn, buckwheat, upland rice, and finger millet, it was suggested to apply 10–20 t/ha FYM along with 5.0 t/ha vermicompost, whereas, for low P and low K, the dosages are 6–12 t/ha FYM and 3–4 t/ha vermicompost. It is suggested that goat/pig/poultry at 3.0 t/ha along with FYM at 5.0 t/ha is a good source of organic zinc supplement in zinc-deficient soils. For spices like ginger, turmeric, and large cardamom, it is suggested to apply well-decomposed FYM along with neem cake at 3.0 t/ha and biofertilizer slurry in rows at planting time in variable dosages under low NPK situations [28]. The temperate climate with high organic matter is highly suitable for fruits like mandarin, chayote, strawberry, pear, etc. in the state. Application of well-decomposed FYM along with neem cake and vermicompost at variable dosages during land preparation and biofertilizer treatment before transplanting can be beneficial for improving fruit quality even under the stress of NPK in soils [29].

3. Year-round cropping systems of major crops for lower and mid hills (300: 2000 m amsl)

For rainfed areas, the predominant cropping systems are maize + beans-vegetable pea; maize + beans-barley; maize + beans-rajma; maize + beans-buckwheat; maize + beans-toria; soybean-buckwheat; and soybean-toria. For irrigated areas, the predominant cropping systems are maize (green cobs)-pahenlo dal-buckwheat; maize-vegetable pea; rice-vegetable pea-maize (green cobs); rice-fenugreek (leafy vegetable)-baby corn; rice-sunflower-*dhaincha* (green manuring); and rice-vegetable pea. Important vegetable cropping systems under low-cost plastic tunnels are broccoli-spinach-coriander-broccoli-coriander system; broccoli-coriander-cabbage-radish-coriander system; coriander-radish-fenugreek-spinach-coriander system; cabbage-local rayo sag-broccoli-coriander system; cabbage-spinach-broccoli-coriander system; and coriander-radish-fenugreek-cauliflower-pak choi system [30, 31]. Important vegetable cropping sequences for low-cost plastic rain shelter are tomato-pea-tomato system; bitter gourd-pea-tomato system; bottle gourd-capsicum-pea system; and sponge gourd-pea-tomato system. Important vegetable cropping sequences for low-cost polyhouse are cucumber-cabbage-tomato system; capsicum-broccoli-tomato system; and cucumber-cauliflower-tomato system. Important vegetable cropping sequences for open condition are okra-pea-cole crops system; okra-cole crops-local rayo sag/leafy vegetables system; dalley chili + local rayo sag/leafy vegetables as intercrop; okra-garlic-local rayo sag/leafy vegetables system; ginger-pea system; and okra-potato-local rayo sag/leafy vegetables system. **Table 1** represents the organic nutrient available in Sikkim from all possible sources.

4. Nutrient management in major crops of Sikkim

1. Maize (*Zea mays* L.): Application of dolomite at 2 t/ha + mixed compost at 2.5 t/ha + neem cake at 0.5 t/ha + vermicompost at 2.5 t/ha (ICAR Sikkim, 2011). Apply FYM at 15 t/ha 20 days before planting along with 150 kg rock phosphate. Neem cake at 150 kg/ha for nutrient supply and control of soil-borne insect pests. Green manuring: sun hemp and dhaincha another alternative. Seed inoculant: *Azospirillum*, *Azotobacter*, and PSB at 20 g/kg seed.

2. Rice (*Oryza sativa* L.): Apply FYM at 10 t/ha to supplement recommended dose of N + P + K for maintaining soil fertility. Practice of raising a pre-kharif crop like green gram, cowpea, sun hemp, or Sesbania for use as green manure. Biofertilizers (blue-green algae or Azolla) capable of providing 20–25 kg N/ha. Neem cake at 150 kg/ha provides protection against soilborne diseases and improves nutrition of rice crops. 5 t FYM + 2 t vermicompost + green manures/weed biomass before 20 days transplanting and 250–300 kg neem cakes during transplanting of rice crop are best nutrient management options. Mixed

Sl. no.	Animal	Livestock population of Sikkim (19th livestock census 2012)	Manure production rate per animal per day in kilograms	Amount of manure produced per day (in kilograms)	Manure/year (tons)	Manure/year On dry weight basis (in tons)
1	Cattle	140,467 CB—126,519 Ind.—13,948	25–30	3,511,675–4,214,010	1281761.375–1538113.65	384528.4125–461434.095
2	Buffalo	703	25–30	17,575–21,090	6414.875–7697.85	1924.4625–2309.355
3	Sheep	2634	2–3	5268–7903	1922.82–2884.595	576.846–865.3785
4	Goat	113,364	2–3	226,728–340,092	82755.72–124133.58	24826.716–37240.074
5	Pig	29,907	5	149,535	54580.275	16374.0825
6	Yak	4036	25	100,900	36828.5	11048.55
7	Poultry	451,966	0.6	271179.6	98980.554	29694.1662
Total				4282860.6–5104709.6	1563243.9–1863219	468973.17–558965.7

Table 1.
Organic nutrient available in Sikkim from all possible sources.

compost at 15 t/ha + neem cake at 1 t/ha. Green manure crops like dhaincha, sun hemp, and cowpea capable of accumulation of 4–5 t/ha of dry biomass and 100 kg N2/ha in 50–60 days.

3. Rapeseed and mustard (Brassica sp.): Apply FYM at 10 t/ha or vermicompost at 5 t/ha during last field preparation. Vermicompost along with Azotobacter and PSB considerably enhances mustard yield. Apply different oil cakes at 0.5 to 1.0 t /ha to meet demand of micronutrient and S demand of the crop. Mixed compost at 5 t/ha + vermicompost at 1.0 t/ha + neem cake at 1.0 t/ha + dolomite at 1.0 t/ha was recommended (ICAR Sikkim, 2011).

4. Soybean (Glycine max) (L.) Merr.: Being a leguminous crop, require less N than other crops. Apply FYM at 5–10 t/ha and incorporate into soil during final land preparation. Apply neem cake at 1 t/ha + mixed compost at 2.5 t/ha + dolomite at 1 t/ha (ICAR Sikkim, 2011). Seed inoculation with Bradyrhizobium japonicum culture (500 g/75 kg seed) + PSB/PSM (6.5 g/ kg seed).

   Buckwheat (*Fagopyrum esculentum* Moench.): Application of vermicompost at 1.5 t/ha recorded the higher grain yield of buckwheat. Efficient crop in extracting phosphorus of low availability from the soil. Azophos seed treatment (APST) + mixed compost at 5 t/ha + neem cake at 0.5 t/ha (ICAR Sikkim, 2011).

5. Baby corn (Zea mays L.): Well-decomposed FYM at 10 t/ha should be applied 20 days before sowing of crop. Baby corn should be inoculated with N-fixing nonsymbiotic microorganism like Azospirillum, Azotobacter, etc. and PSB at 20 g/kg seed.

6. Finger millet (*Eleusine coracana*): Apply 5 t FYM/ha 15 days prior to sowing of the crop. Biofertilizers like Azospirillum brasilense (N-fixing) and Aspergillus awamori (P-solubilizing) apply at 25 g/kg seed.

7. Black gram (*Vigna mungo* L.): FYM or mixed compost at 5 tons/ha enhances the yield. Seed inoculation with Rhizobium strains increases seed yield and uptake of nutrients. Additional nutrient may be supplied through water-soluble organic granules at 5 kg/acre mixed with FYM, vermicompost, or mixed compost.

8. Large cardamom (Amomum subulatum Roxb.): If the land is not terraced, soil base may be made by cutting topsoil from upper half and placed on lower half followed by mulching. At plant base, mulching with easily degradable organic materials is good for conserving both moisture and soil. Mulching improves soil physical condition and fertility. Dried organic matter, leaves, weeds, etc. can be used as mulch. During planting, pits are filled with topsoil mixed with FYM at 1–2 kg/pit. FYM/compost at 5 kg/plant at least twice a year in April to May and August to September is beneficial.

9. Ginger (*Zingiber officinale* L.): Well-decomposed and dried cattle manure or compost at 25–30 t/ha + neem cake at 2 t/ha + biofertilizer (Azospirillum + PSB) at 5–6 kg/ha helps in reducing incidence of rhizome rot of ginger and increases yield. Two months after planting, vermicompost at 5 t/ha should also be applied for better growth and production. Since edible part is rhizome, prior to planting of seed rhizome in soil, a half foot layer (6″) of leaf increases production of ginger by loosening soil texture around seed rhizome at later stages.

10. Turmeric (*Curcuma longa* L.): Needs heavy manuring. Apply FYM at 15–20 t/ha along with 250 kg neem cake or vermicompost at 10 t/ha. Integrated application of FYM at 10 t/ha and vermicompost at 5 t/ha along with 250 kg neem cake. O.M. along with biofertilizers like Azospirillum and Bacillus for better nutrition. Dolomite at 2 t/ ha to ameliorate soil acidity.

11. Mandarin (*Citrus reticulata* Blanco.): Young plants manured once/year, bearing plants twice/year (June to July and after harvesting in December to January) at 10–20 kg FYM/tree or 2–2.5 kg vermicompost/tree. Micronutrients through foliar sprays of water-soluble organic sources or nano-fertilizers at 0.2%. Dolomite at 100–200 g/plant for every second year. Neem cake at 2 t/ha during active growth stage in July to August.

12. Kiwifruit (*Actinidia chinensis*): Plants are heavy nitrogen feeders. Apply well-decomposed FYM at 25–30 t/ha and neem cake at 2 t/ha after vines have several inches of new growth during early spring. During active fruit growth stage, vermicompost at 2 kg/plant should also be given for better growth, production, and fruit quality.

    Cole crops (Brassica spp.): Well-decomposed FYM or compost should be applied at 5.0 kg/m2 along with neem cake at 200 g/m2 at the time of final land preparation. Root dipping of seedlings in Azospirillum + PSB (20%) for 15 minutes at the time of planting. Additional application of vermicompost in cole crops at 1 kg/m2 further improves production.

13. Potato (*Solanum tuberosum* L.): Proper soil fertility management alone accounts for 20.7% of all yield contributing factors. Well-decomposed and dried cattle manure or compost at 25–30 t/ha and neem cake at 2 t/ha should be applied.

5. Identified crops for marketing outside state from Sikkim

The most important crops which have been identified in Sikkim as commercial crop for marketing outside state are large cardamom, ginger, turmeric, buckwheat, cymbidium (flower), and tea. **Table 2** represents the marketing of organic produce in Sikkim.

Agency	Jurisdiction of marketing	Products
Sikkim Marketing Federation (SIMFED)	Within and outside Sikkim	Sikkim mandarin, kiwi, ginger, turmeric, buckwheat, rajma, and vegetables
Farmers Producers Organizations	Within Sikkim	Vegetables
Nature's gift (private entity)	Outside Sikkim	Ginger, turmeric, buckwheat

Table 2.
Marketing of organic produce in Sikkim.

6. Strategies for increasing organic farm productivity in Sikkim

Single-cropping should be avoided and preferably 2–3 crops should be grown together. If for any reason it is not possible to grow mixed or intercrops, then grow different crops in adjacent plots to maintain diversity. At any given time, legumes must occupy at least 30% of total cropping area. The legumes are nitrogen-fixing and can also be good source of mulching from the crop residues. High-yielding varieties require high nutrient inputs; they should be replaced with improved varieties suitable for organic management [31–35]. The same crop or same cropping sequence should not be repeated in the same field in two consecutive seasons/years (except for some legume crops such as mung bean or cowpea), and the field must be rotated every 2–3 years. Adoption of conservation tillage practices for improving soil quality and conserving soil moisture. Cover cropping, in situ residue management and restoration of degraded lands for soil moisture conservation, and improved C-sequestration should be practiced [36, 37]. Integrated farming systems and watershed development with animal, fishery, and suitable cropping for soil and moisture conservation and nutrient recycling should be practiced. The use of water-saving and nutrient-saving technologies, viz., system of rice intensification (SRI) and aerobic rice, should be popularized [38]. Rainwater harvesting: in situ (land configuration, mulching with locally available biomass, etc.) and ex situ (ponds, micro-water harvesting structures like *jalkund*, etc.) for ensuring year-round high-value crop production [38]. Adoption of conservation irrigation practices like drip, sprinklers, etc. in situ biomass management in shifting cultivation instead of biomass burning for improving soil carbon economy and hydrology should be practiced. Adoption of low-cost plastic tunnels, low-cost plastic rain shelters, and greenhouse (low cost) for year-round production of high-value low-volume vegetable crops should be promoted. Sufficient application of organic matter is crucial for soil fertility management especially for achieving satisfactory yields with good-quality product. Integration of integrated farming system is a necessity for organic farming [39]. It is also important to strengthen the animal husbandry section with main emphasis on poultry and piggery because majority of the population consume meat [40]. Besides, both are more profitable ventures. Composting of locally available biomass and construction of vermibeds for vermicomposting is also essential. Need-based crop diversification which allows more crops per unit area per unit time and per drop of water with due consideration of market demand should be enhanced. Introduction of new oilseeds and pulse crops which have yield potentials to meet the pulses and oilseed requirement of the region should be promoted. Recycling of all kinds of biomass and crop residues for minimizing the dependence of nutrient requirement from outside should be practiced [24, 41–45]. Adoption of soil conservation measures and careful soil cultivation that does not lead to soil erosion and conserves the soil moisture should be practiced. Integrated organic nutrient management strategies should be adopted. Uses of biofertilizers, green manuring, and concentrated organic manures like neem cake should be used for proper nutrition. Preventive measures should be adopted to manage pests, diseases, and weeds [46]. Awareness should be created for off-season vegetable production on scientific lines. There should also be an adoption of cool transport chain, pre-cooling units, packing houses, short- and long-term cold stores, etc. for minimizing the postharvest losses. Extension network for dissemination should be strengthened and the adoption of appropriate knowledge/technologies monitored [47, 48]. Agri Export Zone should be identified by the government for export of organic products, and contract cultivation/cooperative farming should be encouraged.

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