

Alternative Fertilizer Options for Nepal - A Critical Review

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Abstract

Food security in Nepal has been a challenge due to low productivity of agricultural crops. Access to fertilizer has been the bottleneck for increasing productivity in Nepalese agriculture. The ever-increasing price for fertilizer and unreliable supply will put further pressure on Nepalese agriculture in the future. Therefore, an alternative fertilizer plan based on recovering fertilizer products from various agricultural and municipal organic wastes has been explored. Developing fertilizer products from a wide range of organic wastes has been a topic of interest world-wide, and recently there has been major progress on new methods of organic recycling. For example, Biotech Ltd has patented an aerobic thermophilic digester technology that is in use for the rapid composting of various organic wastes with high fertilizer value. Rapid digestion of varied organic wastes, including poultry wastes, and their co-digestion with other organic wastes (e.g., food, sludge, green waste) were evaluated to produce a wide range of composted products that can be further composted or to produce dry organic pellets, granules or to develop custom blends of fertilizer in an organo-mineral mix as a complete fertilizer suitable in different cropping industries. Pelletization and dry organo-mineral fertilizer products have longer storage, are cost effective to transport and in land application. Innovation and practice change in the production of organo-mineral fertilizers complemented with best practice management in crop production, are expected to result in transformational gain of agriculture productivity and profitability in Nepal.

Keywords

Fertilizer, plant nutrients, sustainable agriculture, organic waste

1. BACKGROUND

We discuss the role of agriculture in the Nepalese economy, causes of poor agricultural productivity, issues related to poor fertilizer supply chain function, and suggest use of alternative fertilizer products that provide the sustainable soil management options required to gain productivity of agricultural crops in Nepal.

1.1 Role of Agriculture in the Nepalese economy

Nepal is currently on the verge of an economic transformation. Agriculture remains the principal

economic pillar, employing ~65% of the population and contributing 32% of the national GDP of \$33.66 billion in 2017. Out of the total 147,181 square kilometer land area of Nepal, agricultural, forestry and pasture covers ~28%; ~40% and ~12% of land use respectively [1]. Traditional agriculture in Nepal features integrated farming (mixed farming operations consisting of agroforestry, animals and crops), that offer closed loop, low input, subsistence and sustainable farming that do not solely rely on inorganic fertilizers for plant nutrition. However, a post green revolution since 1965 has brought

new high yielding crop varieties that require fertilizers for intensive farming, in a quest for a rapid increase in production and productivity to secure food self-sufficiency, to feed a growing population. This approach has not been successful for driving sustainable agricultural productivity and food supply in Nepal. The failure has been largely ascribed to inadequate and inefficient coordination of the supply of inputs viz, high yielding varieties with fertilizers, irrigation, and appropriate agronomic practices for diseases and pest management, harvest and postharvest operations, which are essential for securing the green revolution results achieved in other countries.

1.2 Food sufficiency in crisis- a challenge before the agriculture economy

Nepal exported more food than it imported until the early 1980s. It started to become a net importer of food, particularly cereals, in the early 1980s. But until 2002, the import was only marginal, accounting to about 1.3% of the available food [2]. By the 1990s, India was rebounding with higher productivity and volume in agricultural commodities, mainly riding on the success of the Green Revolution and favorable agricultural policies and support from the government, conferring competitive advantage to Indian produce compared to Nepalese ones. The Agricultural Perspective Plan of 1995, which guided Nepal's agriculture practice for two decades aimed to improving crop productivity but the commercialization of agriculture did not become a reality. In 2001 Nepal imported food and farm products valued at \$11.84 million annually from India. By 2021, the food import

soared 78 times reaching \$1 billion, largely paid by remittance income of Nepalese.

In 2021, Nepal's largest food import was rice (1.29 MT) valued at \$402.91 million. Two decades earlier rice imports amounted to 8,025 tonnes worth \$1.74 million, showing Nepal is becoming dependent on processed agricultural goods at a fast rate. Imports of processed food in 2020-21 reached 101,391 tonnes, a ten-fold increase over the previous year. Importing agricultural commodities to meet domestic demand has become a common practice in a globalized economy; however, it can be a serious issue when exports from the country remain stagnant or in decline while the imports soar at an alarming rate. Economists argue that Nepal should produce high value foods to harness comparative advantage, e.g. chayote squash from Ilam district, pears from Palpa district, and rainy season vegetables from the hills and mountains of Nepal.

2. FERTILIZER CHALLENGES FOR NEPALESE AGRICULTURE

2.1 Mineral Fertilizer's Use in Nepal

Mineral fertilizer was first introduced to Nepal in the 1950s, and organized supply began in 1965 by the agriculture input supply corporation (AISC) which imported 4200 tons of fertilizers. To promote fertilizer supply and use the government reintroduced a fertilizer subsidy scheme in 2009 with AISC as the sole importer and distributor for the country. Based on data for formal imports, fertilizer use in Nepal increased from less than 10,000 nutrient tons in 1970 to over 90,000 nutrient tons in 1994/1995 and remained at that level until 2012/2013. During 2000-2013,

households applied less than 30 kg/ha of fertilizer nutrients. The low use of fertilizer application was attributed with persistently low crop yields in Nepal. Since then fertilizer consumption has increased by 33% per year. The yearly consumption in 2018 reached to 86.9 kg/ha from the 65.5kg/ha used in 2017. The current estimate for fertilizer use suggests that Nepal needs approximately 500,000 to 800,000 metric tons of fertilizer per year. Household use of fertilizer nutrients is still consistently low compared to other south Asian countries.

Urea (46% N) and DAP (18% N and 46% P) are widely used (80%) fertilizers in Nepal. Their preference is associated with high nutrient concentration, offering transport economy for reaching remote and mountainous regions. An estimate suggests that 70% of fertilizer supplied in the Terai region is primarily used for rice, whereas the Hill and Mountain Regions, receive negligible fertilizer for use with rice, wheat and maize grown in these areas. With increasing use of N fertilizers in farming, issues of micronutrient deficiency (B, Zn, and Mo) surface progressively, particularly in areas where high yielding crop varieties are intensively grown in heavily N fertilized soil.

2.2 Mineral Fertilizer Supply Chain Issues

The twenty-year agriculture perspective plan (APP) started in 1997 identified chemical fertilizer as an engine of agriculture growth for Nepal. Fertilizer was expected to contribute 64 to 75% of the targeted total agriculture growth. APP envisaged an increase in fertilizer usage from 31 kg nutrient/hectare of the base year 1995 to 131 kg nutrient/hectare by 2017. However, fertilizer

use in Nepal never reached to APP target for 2017. Nepal's annual fertilizer demand stands at 0.8 MT and fertilizer use in 2020 was only 86.9 kg/ha, about half the target.

Low use of fertilizer products in Nepal is largely related to poor access caused by inefficient import supply, poor distribution, lack of quality control, high cost for fertilizer and poor agronomic advice and information on use of fertilizers for different crops and soil conditions.

2.3 Challenges for Excessive Dependency on Mineral Fertilizer

Nepalese farmers have for a long time been impinged by a fertilizer crisis brought about by soaring fossil fuel prices and lack of industry consolidation. The price of synthetic fertilizer has more than doubled since 2020, causing great stress in farming communities. Fertilizer, as a source of plant nutrients, is a crucial input directly impacting agricultural production and also mediates efficiency of other production inputs (e.g., water) in farming. Access to fertilizers on time, with a standard quality and steady price, is a stabilizing input for farming, and has been a large cause for the divide between rich and poor farmers in many communities and countries.

Increasing dependency on inorganic fertilizer and its sole application for plant nutrition has caused long-term changes in soil physical, chemical and biological properties contributing to poor soil fertility. There is wide-spread realization of long-term soil fertility losses when all essential plant nutrients are not replenished in balanced ways, as applying N fertilizer alone cannot sustain higher yields due to limitations associated with the deficiency of other nutrient elements. An organic

based complete fertilizer application to soils can potentially overcome this issue.

We strongly argue that producing more synthetic fertilizers should not be the only answer to this serious challenge. Nations should also provide support for nature-based, alternative options, including low input farming practices that help farmers reduce or forgo synthetic fertilizers, and biological products that substitute for harsher chemical inputs.

Considering existing socio-economic, cultural, trade and policy constraints for fertilizer management, soaring fertilizer price, and the adverse effects of unbalanced use of the inorganic fertilizers, the country needs alternative fertilizer options to achieve the desired growth in agriculture and food production.

3. ALTERNATIVE FERTILIZER OPTIONS FOR NEPAL

Based on the source of the materials, the fertilizers can be classified based on source as synthetic, natural (in organic and organic fertilizers) and biological (see figure below). The fertilizers are also classified based on the formulation as straight, mix, complete, incomplete, soluble and insoluble, pure or blends.

3.1 Reformulated synthetic, chemical, or mineral fertilizers

Synthetic fertilizers are also known as chemical and mineral fertilizers. Synthetically derived fertilizers are manufactured from minerals, gasses in the air and inorganic waste materials. These are best known for being fast-acting and coming in a variety of forms such as liquid, pellet, granule, and spike. Common

fertilizers currently in market, e.g. Urea, DAP are pre-dominantly synthetic fertilizers. New innovation in synthetic fertilizers such as slow or controlled release fertilizer (e.g. sulphur coated urea), nitrogen inhibitors in N fertilizer, Nano urea, new formulations of liquid fertilizer that can be applied through drip irrigation have been reported to have greater fertilizer use efficiency compared to the conventional fertilizers products [3].

3.2 Natural of Organic Fertilizers

A natural or organic fertilizer relies on plant, mineral, and animal sources for its nutrients. Ingredients such as compost, poultry and livestock manure, bone meal, blood meal, fish meal, greensand, rock phosphate, alfalfa meal and kelp are common in natural fertilizers (more on some of these in a bit). Organically derived fertilizers typically have a lower nitrogen, phosphorus, and potassium (NPK) analysis than synthetic fertilizers, and are slow release, hence support plant nutrition for long periods of time. Therefore, the effects of organic fertilizers on crops are usually subtle. Organic fertilizers also stimulate beneficial soil microorganisms and improve soil structure. Soil microbes play a key role in converting organic fertilizers into soluble nutrients that can be absorbed by plants. Organically derived fertilizers often provide the secondary and micronutrients plants need, that are usually absent in synthetic fertilizers. The simple comparison of organic vs synthetic fertilizers effects on plants and soil is given below.

3.3 Biofertilizers

Biofertilizers are substances containing a variety of microbes that have the capacity to enhance plant nutrient uptake by colonizing the rhizosphere and make nutrients easily accessible to plant root hairs. The main sources of biofertilizers contributors are bacteria, fungi, and cyanobacteria (blue-green algae). The most striking relationship that these have with plants is symbiosis, in which the partners derive benefits from each other, particularly in the legume family of crops.

Common biofertilizers are:

- i. Nitrogen fixing biofertilizers (symbiotic nitrogen fixing bacteria, e.g. *Rhizobium*, and free-living nitrogen fixing-cyanobacteria)
- ii. Phosphate solubilizing biofertilizer (e.g. *Bacillus*, *Pseudomonas*, *Aspergillus*)
- iii. Phosphate mobilizing biofertilizer (e.g. *Mycorrhiza*)
- iv. Plant growth promoting biofertilizers (e.g. *Pseudomonas spp*)
- v. Potassium solubilizing biofertilizer (e.g. *Aspergillus niger*, *Bacillus spp*)
- vi. Potassium mobilizing biofertilizer (e.g. *Bacillus spp*)
- vii. Sulfur-oxidizing biofertilizers (e.g. *Thiobacillus*)

Biofertilizer production essentially depends on the availability and isolation of targeted microbes from a specific environment, including the rhizosphere and plant tissues. Candidate microbes are cultivated and multiplied using a fermenter under optimal growth conditions.

Protocols for mass multiplication of these biofertilizer species are available and commercial production of biofertilizers products has been well established in a number of countries for mass scale use of biofertilizer products by growers. Establishment and development of an appropriate biofertilizer industry is highly timely for Nepal as well. Biofertilizers are well known for their cost effectiveness, environment-friendly nature, and composition [4]. The Indian biofertilizers market is expected to grow from \$110.07 million in 2022 to \$243.61 million by 2029, exhibiting a CAGR of 12.02% in the forecast period.

Biofertilizer manufacturers, suppliers and Indian exporters is given in the link (<https://www.maharashtradiirectory.com/product/bio-fertilizers.html>). Commonly produced biofertilizer in India can be found in this link (https://agritech.tnau.ac.in/farm_enterprises/Farm%20enterprises_%20biofertilizer.html)

3.4 Phyto-accumulators and phyto-extractors

Phyto-accumulators/phyto-extractors are plant species which have the capacity to absorb and accumulate specific nutrient elements from soil. Identification of plant species with high micronutrient uptake favors crop nutrient management in organic farming. Use of plant biomass in the form of green manure, mulch or as compost alleviate micronutrient deficiency in organic farming. Phyto miner crops such as *Glyricidia maculeata*, *Calatropis gigantea* etc are popular for their high nutrient contents and use for green manure [5]. Fertilizer trees enhance soil health by drawing nitrogen from the air and transferring it into the soil through their roots and

leaf litter, replenishing exhausted soils with rich sources of organic nutrients. They can also bring nutrients from deep in the soil to the surface for crops with shallow roots. This method ensures nutrient recycling by the virtue of trees that contribute the crop nutrient use efficiency.

4. FUTURE FERTILIZERS OPPORTUNITIES FOR NEPAL

Organic wastes are potential resources for the future fertilizers for farming worldwide. These vast resources with both diffused and point source in origin can be collected and processed for number of uses including biogas, compost, organo-mineral fertilizers and soil amendment products. Technologies for collection, separation, digestion, composting and fertilizer product development using organic wastes are rapidly advancing worldwide. Nepal should proactively take this emerging business opportunity for addressing both the issue of waste management, while also developing innovative fertilizer products to address the acute shortage of fertilizer the country experiences every year.

4.1 Organic Waste to Fertilizer

Agricultural waste (on farm and in food processing industries)

Agricultural waste is an unwanted or unsalable material produced wholly from agricultural operations directly related to the growing of crops or raising of animals for the primary purpose of making a profit or for livelihood. In Nepal, large quantities of agricultural waste arises from livestock, poultry and aquaculture operations. Significant waste originates in the cropping sector e.g., fruit and vegetable farming. The accounting of agricultural waste in Nepal is not up to date, hence data for all agricultural wastes

is unavailable. We present only a case study of the poultry industry to showcase the volume of waste in the poultry sector.

The annual liquid and solid waste production from the poultry industry in Nepal is 618.86 million liters and 2.7 million tons respectively. 81.9% of liquid waste generated from sullage and 18.1% from sewage. 99% of poultry solid waste was generated from poultry manure i.e. 2.66 million tons/year. Poultry farms in Nepal emit 30.41 Gg CO₂-eq of methane gas (CH₄) annually from manure management. With the assumption of 50% moisture content in poultry manure, the dry weight of poultry manure waste is 1.33 million tons/year. The NPK load in the broiler is about 3.3, 1.3 and 1.3% respectively on the dry weight basis [6], therefore, potential recovery of NPK from poultry is about 43.9, 17.7 and 17.7 tons from poultry litter alone. A large quantity of waste from poultry processing and other livestock-based operation such as piggeries are not included in these calculations.

Municipal solid waste

Solid waste management in municipalities of Nepal is a major issues that requires a sustainable solution. Detailed data on municipal waste in Nepal is patchy. Taking baseline data from a solid waste management in Nepal report by the Asian Development Bank 2013, estimated waste projection for 2017 has been made. The projected data shows waste generation in municipalities of Nepal is about 3023 tons per day and the average per capita waste generation is 0.223 kg/person/day. On average the composition of waste is primarily decomposable about 60% and about 25% is recyclables such as plastics, papers

and metals. With the help of Multi Criteria Decision Matrix (MCDM), this paper suggests that the suitable methods of waste management for Nepalese municipalities are waste to bio-energy and fertilizer production [7].

After the waste is sorted, its physical components were determined to be; organic materials (73.7%), and Laboratory analysis of the organic components of the waste indicated that the mean nitrogen (N), phosphorus (P), and potassium (K) contents were 11.0, 3.2, and 10.7 g kg⁻¹, respectively. The mean contents of other elements were calcium (Ca) (87.7 g kg⁻¹), sodium (Na) (18.4 g kg⁻¹), and sulfur (S) (2.3 g kg⁻¹). The mean organic-matter content of the organic components of waste was 223.7 g kg⁻¹. The physical and nutrient contents of the waste varied widely within and between municipality. The high content of organic matter and some essential macronutrients in the waste suggest its high value for use in the production of organic and organo-mineral fertilizers for agriculture use [8]. With the daily estimate of 3023 ton solid waste containing 70% organic matter, with estimated moisture contents of 50%, could recover daily 11.64, 3.39 and 11.32 ton of NPK respectively. On a yearly basis the potential recovery can be up to 4249, 1236 and 4132 tonnes of NPK respectively. This equates to about 50% of the total N fertilizer currently imported for use in agriculture in Nepal.

Biosolids

Municipal waste in developed countries also include biosolids. Biosolids – primarily dead bacteria – from sewage plants, are rich in nutrients and can potentially be used as fertilizers.

Currently Nepal does not have an organized sewage system for collection and processing of biosolids, but these could be a future potential source when new regulations for the development of sewage become mandatory in new urban development.

4.2 Processing of organic wastes for fertilizers product

Conventional composting

Recycling of organic waste to compost provide a range of benefits related to nutrient recovery, environmental benefits, soil health benefits, reducing greenhouse gas emission and improving soil properties for nutrient and water holding capacity. Composting is a great way to recycle organic wastes as it reduces the volume of the waste stream (as about 0.5 – 0.6 tons of compost at 50% moisture is recovered from 1 ton of organic wastes with 60% moisture), this also cuts methane emissions from landfills, improve soil health and lessens soil erosion, conserves water and reduces the burden of personal food waste.

Compost quality standards are very important for developing consistent products that produce predictable results. Using very heterogeneous materials for diverse organic waste can be challenging for producing a consistent quality of compost. Compost quality standards are country specific. The Australian Standard for Composting (AS4454-2012) requires the heap be turned a minimum of three times (outside to inside) with the internal temperature reaching at least 55°C for three consecutive days before each turning to ensure adequate pathogen destruction (<https://www.soilwealth.com.au/imagesDB/news/AS4454-2012A1.pdf>).

In spite of the numerous benefits reported for compost, large scale adoption of compost for replacement of fertilizers is still constrained by high costs of compost for purchase, transport costs, storage and field application, inconsistent quality of the product and need for large quantity for complete replacement of fertilizer [9].

Vermicomposting

Vermicompost involves earthworm for digestion and aerobic decomposition of organic wastes, and the activity of micro- and macroorganisms at room temperature. Some of the commonly used feedstocks for vermicompost are food scraps, yard waste, sawdust, animal manure and bedding material. Manure-based vermicomposts tend to have higher levels of nitrogen and other nutrients than the previously mentioned feedstocks, but vermicompost can be successfully produced from urban organic wastes and from plant sources. Mixture of leguminous and non-leguminous crop residues enriches the quality of vermicompost. Vermicomposting, or worm composting, produces a rich organic soil amendment containing a diversity of plant nutrients and beneficial microorganisms. Vermicomposting is the process by which worms are used to convert organic materials (usually wastes) into a humus-like material known as vermicompost. Vermicompost is better than compost due to its higher nitrogen (2-3%), phosphorus (1.55-2.25%) and potassium (1.85-2.25%) content, and its ability to improve soil structure and increase water-holding capacity. Vermicompost is an ideal organic manure for better growth and yield of many plants. Higher production cost, need of extra care for worms, space, time and the

occurrence of worm pests and diseases are some of the reported disadvantages associated with vermicompost compared to the compost. Vermicomposting is rapidly expanding to on-farm vermicomposting and vermiculture in many countries in the world. Numerous handy resource materials are available as a manual for operation (<https://urbanwormcompany.com/vermicomposting-ultimate-guide-beginner-expert/>).

Earthworm feeding can reduce the volume of organic waste by 40–60%. Each earthworm weighs about 0.5 to 0.6 gram, eats waste equivalent to its body weight each day and produces cast equivalent to about 50 percent of the waste it consumes in a day. The moisture content of castings range from 32-66% and the pH is ~7.

Red earthworm species, like *Eisenia foetida*, non-burrowing earthworms, are efficient composters as they eat 10% soil and 90% organic waste; converting this into vermicompost faster than burrowing earthworms. They thrive in temperatures ranging from 25 to 30°C and 40–45 percent moisture levels in the pile. Small-scale vermicomposting (5-10 tons/year) are customised for personal requirements, whereas commercial scale vermicomposting recycle large quantities of organic waste in modern facilities with the production of more than hundreds of tons annually. Large scale adoption of the vermicompost products is also constrained by similar reason as for the compost.

Aerobic thermophilic digestion for rapid composting

Aerobic composting is decomposition of organic matter using microorganisms that require oxygen.

The microbes responsible for composting are naturally occurring and live in the moisture surrounding organic matter. Oxygen from the air diffuses into moisture and is taken up by the microbes. As aerobic digestion takes place the by-products are heat, water and CO₂.

The heat produced in aerobic composting is sufficient to kill harmful bacteria and pathogens as these organisms are not adapted to these environmental conditions. It also helps support the growth of beneficial bacteria species including psychrophilic, mesophilic, and thermophilic bacteria which thrive at higher temperature levels.

The thermophilic aerobic digester of PBT Ltd Taiwan takes 4-8 hours for complete digestion of the organic waste in a vessel aerobic composting process in the presence of thermophilic bacterial inoculants. The digested product is free of major compost pathogens such as *E. coli*, *Salmonella*, *Listeria* etc. The digested materials can go through a week-long fermentation phase for maturation, or for conventional composting or processed as pellets or granulated fertilizer in a dry form for ease of storage, transport and handling. This is a close loop in-vessel system generally housed under the protection from weather. No leachate is produced as any surplus moisture is extracted as water vapour which can be condensed and reused for the digester or watering nearby vegetation.

These kind of in vessel aerobic thermophilic systems are gradually gathering interest due to their precision control of the composting process, closed loop operation, rapid compost process and

pathogen elimination. These also take less space and allow further value-added compost product formation, their adoption by industry is likely in the near future. In vessels system also allows for bringing automation and strict process control that allow developing custom designed compost as per the need of the user. The HotRot Compost, as commercialized by a NZ company is an example

(<https://www.globalcomposting.solutions/how-hotrot-technology-works>)



Figure 1: Rapid composting pilot plant set up for the monitoring of temperature and mixability in a thermophilic digester

Waste to Biogas Option

A large proportion of Nepal's municipal waste is biodegradable, that can provide feedstock for Bio-CNG digesters, producing energy and fertilizer from biodegradable wastes. Nepal currently hosts more than 0.3 million domestic scale biogas operations. Scaling up for large-scale biogas plants to accommodate large volumes of urban and agricultural waste is very timely. There are more than 344 large-scale biogas plants in the country, but only a few of them have digesters larger than 3,000 m³, which is considered a threshold for commercial viability [10].

A recent waste management baseline survey of Nepal indicates that urban municipalities in Nepal generate nearly 2,400 metric tons per year of solid waste on average, more than half of which is organic. This means that almost 10,000 metric tons of purified biogas (bio-CNG) with more than 90% methane concentration can theoretically be produced in the municipalities [10].

An additional 1.5 million metric tons of bio-CNG per year could be generated using livestock manure across the country. Even if we only use 10% of this waste, we could still generate nearly 145,000 metric tons of bio-CNG per year - equivalent to more than 10 million LPG cylinders - and help reduce Nepal's LPG imports by 30%, narrow the trade gap with India and save foreign currency. Furthermore, the spent effluent from the digesters, as a by-product of biogas plants, could substantially reduce Nepal's imports of chemical fertiliser, and promote organic farming [10].

Organo- mineral Fertilizers

The combination of animal manure and mineral fertilizer to produce *organo-mineral fertilizers (OMF)* is a new concept in animal waste management. Organo-mineral fertilizers are characterized as a mixture of organic and mineral fractions and can be produced in several N, P and K proportions suitable for crop requirements. Usually, as a derivate to regional organic sources, the final product can be granulated, pelleted or powdered.

Compared with animal manure, OMF have higher nutrient concentration so that lower application rates can be used. The production of OMF

produces a more stable, balanced, and uniform product with predictable nutrient availability and nutrient release. The advantage of OMF over mineral fertilizers is the supply of a range of macro and micronutrients in addition to organic matter, can improve plant growth parameters such as yield and nutrient uptake to a greater degree, than when manure or fertilizers are used alone [11].

Organic Fertilizer Product Development

An organic waste to fertilizer production line uses highly variable organic wastes as the raw material (such as organic waste, straw, excrement from livestock and poultry, cake, meal, agricultural and sideline product), which impact the consistency of the final product. Latest technologies on rapid composting digestors, and the control and automation of the system allows for controlling the variability and result in better consistent products. This process allows for pathogen control and custom blend of compost with inorganic fertilizers, development of products that can be stored, more easily transported and used in the field using current fertilizer applicators.

Equipment Operation Flow for Organic Fertilizer Granulation Production Line

- i. The raw material is accumulated and fermented. The production of any kind of qualified and high-quality organic fertilizer must go through compost and fermentation.
- ii. Mixing and crushing.
- iii. Crushing machine includes semi-wet material crusher, chain crusher, hammer crusher, etc.; mixing machine includes

- double shafts horizontal mixer, horizontal mixer, single shaft mixer, etc.
- iv. Granulation.
 - v. In the production of organic fertilizer, the choice of granulation method is very important. At present, there are many different ways, like disk, drum, or extrusion types.
 - vi. Drying.
 - vii. Most materials have formed granules after granulation, but at this time the granules still need to be dried because their water content and strength cannot reach standards.
 - viii. Cooling.
 - ix. The dried granules are sent to the cooler by a belt conveyor to cool to near room temperature, so that the strength of the granules is improved and its water content reduced.
 - x. Screening.
 - xi. Some powdery materials still exist in the cooled granules, so it is necessary to sieve out the fine powder and large particles, and then let them be processed by certain machines.
 - xii. The final products should be coated, then a protective film formed on the surface of particles to isolate them from outside air.
 - xiii. The resultant products are packed by automatic packaging machines.

5. INTEGRATED SOIL FERTILITY MANAGEMENT- BASIS FOR SUSTAINABLE CROP PRODUCTIVITY

Fertile and healthy soil is the foundation for sustainable crop productivity. Soil fertility is the ability of soil to sustain plant growth and optimize crop yield. Fertilizer management is one of the aspects of the soil fertility management, therefore, developing fertile soil needs a holistic approach, not just for fertilizer management.

Advancing food security and environmental sustainability in farming systems requires an integrated soil fertility management approach that maximizes crop production while minimizing the mining of soil nutrient reserves and the degradation of the physical and chemical properties of soil that can lead to land degradation, including soil erosion. Such soil fertility management practices include the use of fertilizers, organic inputs, crop rotation with legumes and the use of improved germplasm, combined with the knowledge on how to adapt these practices to local conditions. A new paradigm for nutrient management is required (feed the soil not the crop), underpinned by reducing crop fertilizer demand, utilizing legacy soil nutrients/fertilizers, using recycled and recovered nutrients/fertilizers, and increase fertilizer/nutrient recovery.

6. CONCLUSION

Fertilizer imports and supply to farmers has been continuously challenging in Nepal for a long time. The recent failure in supply chains has been further compromised due to increasing fertilizer prices and global transport disruption caused by COVID and Ukraine-Russian war. The declining food security in Nepal has been well linked to a poor fertilizer supply chain and inaccessible fertilizer products delivered on time to the

growers. In the face of rapidly declining soil fertility status of agricultural soils in Nepal, a complete remodeling of fertilizer supply chains of alternative fertilizers need to be considered. We have discussed developing alternative fertilizers utilizing wide-spread organic wastes, utilizing a number and aerobic and anaerobic digestions methods, and vermiculture for rapid composting. An integrated and holistic approach for soil fertility management harnessing the potentials of all other alternative fertilizers (biofertilizers, natural fertilizers, legumes, phytoaccumulators) has also been recommended.

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