Soil Fertility and Fertilizer Management Strategy for Myanmar

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Foreword

Agriculture sector performance is key to economic growth and food security in Myanmar. Recently, the Republic of the Government of Myanmar (GOM) has engaged in the preparation of numerous strategic action plans and strategy-related documents that target improved agriculture sector performance.[1] Each document identifies ***soil degradation*** (problems related to soil erosion, soil fertility, and soil salinity) as a significant concern that must be properly addressed to support sustainable agricultural growth and the government's goal of transforming the agriculture sector.

The Ministry of Agriculture, Livestock and Irrigation (MOALI) is responsible for establishing the policy framework and gathering the support needed to lead the agriculture sector to success. MOALI has requested that the International Fertilizer Development Center (IFDC)[2] assist with these efforts, to develop a strategy to guide the government in strengthening its fertilizer-related policies and programs to contribute to sustainably improving the quality and productive capacity of Myanmar's soils.

The adoption of technologies and practices that are more mindful of landscape and ecological resources is fundamental to sustainable agricultural production. Improving smallholder farmers' access to and use of appropriate fertilizer-related technologies, including high-quality chemical fertilizers, organic materials (on-farm and commercially available materials), and biological materials, is targeted. Critical to these goals is public-private partnership and the improvement of the public and private sectors' performance with respect to their roles in: (1) needs-based fertilizer research and development programs, (2) dissemination of research results to relevant stakeholders, (3) fertilizer-related technology transfer to agro-input dealers and farmers, and (4) assurance that farmers have access to high-quality fertilizers appropriate to specific zones and crops.

[1] Including, among others: *Five Year Plan (2016/17 – 2020/21); Myanmar National Action Plan for Food and Nutrition Security; Myanmar Climate-Smart Agricultural Strategy; Myanmar Rice Sector Development Strategy; White Paper – From Rice Bowl to Food Basket; White Paper – Vegetables; Food Value Chain Road Map; Agricultural Policy (October 2016); Agricultural Development Strategy and Investment Plan (draft, December 2016); Myanmar's Moment: Unique Opportunities, Major Challenges by McKinsey Global Institute (2013).*

[2] IFDC is a soil fertility and fertilizer research and development organization established in 1974 following a recommendation made during the World Food Conference (1974) to proactively address the threat of a dwindling world food supply. IFDC focuses on improving fertilizer-related technologies and the productive capacity of soils to support sustainable agriculture worldwide.

This document outlines provisions of the Soil Fertility and Fertilizer Management Strategy (SFFMS) for Myanmar. It was jointly developed with guidance from and in close collaboration with MOALI. Extensive discussions were held with key public and private sector stakeholders[3] to advance understanding of the issues, challenges, and opportunities to proactively contribute to the improvement of Myanmar soils. Focused on fertilizer-related issues that impact soil fertility and crop production, the SFFMS will contribute to improvements in food security. It will advance farmer participation in markets and rural income growth, improve efficiency in public and private sector systems that impact fertilizer use (i.e., knowledge development, technology introduction/transfer, and investment planning), and reduce the impact of fertilizers on the natural landscape and ecological resources. With additional information and insights gained in the National Soil Fertility and Fertilizer Management Strategy Workshop held in Nay Pyi Taw on 20 October 2017, this draft is intended to provide the foundation of the strategic plan for the Soil Fertility and Fertilizer Management Strategy for Myanmar.

[3] Discussions were held with numerous stakeholders, including (i) government officials within the MOALI structure and other key ministries (the Ministry of Commerce, Ministry of Electricity and Energy, Ministry of Natural Resources and Environmental Conservation), (ii) Yezin Agricultural University, (iii) international and development assistance organizations (Food and Agriculture Organization of United Nations, World Bank, United States Agency for International Development, Australia Center for International Agricultural Research), (iv) development assistance projects/programs (Livelihoods and Food Security Trust Fund and Michigan State University), (v) farmers and farmer organizations, and (vi) private sector (fertilizer importers/processors/value chain members, and private financial service providers).

Soil Fertility and Fertilizer Management Strategy for Myanmar

Executive Summary

The productive capacity of Myanmar soils is an increasing concern. Many years of poor agriculture and land management practices have led to serious land degradation issues. There is increased awareness that achievement of the GOM's national five-year plan targets for agriculture is threatened by the declining quality of Myanmar's agricultural soils.

Agricultural transformation is targeted in the MOALI strategic plan, with emphasis on the rapid expansion of modern agricultural technologies. Focus areas include improved use of high-quality, high-yielding variety seeds, appropriate high-quality fertilizers, and crop protection products, along with farm mechanization and improved water management. Agriculture and related product/commodity-specific strategic plans are in various stages of completion to ensure that technology advances are appropriate to the Myanmar cultural, social, and agro-economic context. Well-integrated into each of the strategic plans are measures to mitigate risks linked to negative environmental consequences (including climate change) that may be associated with modern agricultural technologies.

Agriculture sector performance in Myanmar is highly dependent upon soil quality. An adequate supply of the 17 essential plant nutrients, primarily available to crops through the soils, is needed for optimum yields. Soils have an extensive ecological structure with living organisms and characteristics that impact moisture availability, crop nutrient supply, and physical support for crop growth. Organic matter is a key component of soils and directly impacts the yield capacity of soils. The living organisms in the soil continually break down minerals and organic matter to fortify the nutrient content of the soil. Over time, harvested crops such as rice remove far more nutrients that can be supplied by soil ecosystems. While fallow periods allow for some natural replenishment of soil nutrients, continuous cropping of annual and multiple crops per year leads to rapid depletion of soil nutrients and, unless residues are left in the field, depletion of organic matter as well.

Soil nutrient restoration can be accomplished to a limited extent through application of organic materials, such as crop residue, animal manure, and green manure. Application of biological materials may also be effective in improving crop nutrient recovery from the atmosphere and/or the soil. However, it is only chemical or inorganic fertilizers that can deliver the high levels of essential nutrients needed in modern, high-yield agriculture with continuous cropping. Inorganic fertilizers contain various (often very high) levels of essential nutrients.[4] Such high nutrient values allow for farmers to deliver the recommended levels of nutrients to soils and crops without overburdening physical delivery systems. Further, the cost per unit of nutrient in high analysis fertilizers is generally quite low vis-à-vis nutrient values available in other commercial materials and manures. For the foreseeable future, there will continue to be a heavy reliance on inorganic fertilizers to support sustainable improvement in crop yields.[5] However, despite the benefits of using inorganic fertilizers, it is also critically important that researchers and other stakeholders in Myanmar stay alert to new opportunities that will lead to farming systems that are more mindful of the natural landscape and ecological resources.

Although Myanmar has had a long history of low fertilizer use, the fertilizer market has expanded rapidly since 2008. While data are limited, it is estimated that during the past decade, the fertilizer market in Myanmar has grown at a compound growth rate of 10-15% per year to about 1.6 million metric tons (t) in 2016. Despite the recent growth in demand, the intensity of fertilizer use in Myanmar is only about 25% of the fertilizer use level globally (fertilizer use per hectare of agricultural land). The current fertilizer use practices also result in unbalanced nutrient applications, with an N:P:K use ratio of 6.5:1.6:1. One of the key ways to improve fertilizer use is to enhance farmer knowledge of the specific crop and soil nutrient needs and the fertilizer products (nutrient grades/formulations) that will best match those nutrient needs. Choosing which fertilizer to use is often one of the most important decisions a farmer has to make. However, Myanmar farmers have limited knowledge of modern agricultural technologies, including fertilizers. Additionally, no top-down recommendation currently exists in Myanmar for fertilizer based on crops and agro-ecological zones. Soil

[4] Inorganic fertilizer is manufactured through complex chemical processes and contains high nutrient values. In the case of solid products, such as diammonium phosphate and urea fertilizers, nutrient values are 64% and 46% (by weight). Such high-analysis products are key to global agricultural production as it is known today.
[5] Inorganic fertilizer is one of the highest cost factors in crop production. Its use also impacts the natural landscape and soil ecosystems and is identified as a key contributor to global climate change. Site-specific research promoting integrated use of inorganic and organic fertilizers could result in sustainable and profitable agriculture with reduced environmental impact.

testing, which is essential to improving soil nutrient management, is not widely done. Therefore, for those farmers who do use fertilizers, recommendations from their neighbors and/or agro-input dealers are a major influencing factor in their own decisions. Unfortunately, local agro-input dealers also have limited knowledge about fertilizer products and their efficient utilization.

Private sector presence in the Myanmar fertilizer market has grown rapidly with the enactment of the Fertilizer Law in 2002 (revised in 2015). Fertilizer supply is based on the domestic manufacture of ammonia/urea (by government-owned and -operated factories) and imports, with imports accounting for about 80-90% of supply. The private sector is responsible for all fertilizer imports (valued at more than U.S. $300 million in 2016) and domestic marketing through a growing dealer network comprising more than 5,000 licensed dealers. The dealer network extends to all key agricultural areas. In addition to official marketing channels, "unofficial" fertilizer imports from neighboring countries do sometimes occur. Fertilizer prices are based upon market conditions, heavily influenced by global fertilizer market prices (due to the fact that 80-90% of supply is based upon imports), logistics costs, and competition.

Fertilizer quality is a widespread concern in Myanmar as most stakeholders (farmers, government officials, and many in the private sector) have low confidence that the fertilizers they have access to are of a consistently high quality.[6] The Land Use Division (LUD) within the Department of Agriculture provides fertilizer inspection and analytical services to ensure quality assurance. Due to capacity limitations and other factors, its effectiveness in quality assurance is limited.

The Fertilizer Law (amended in 2015) provides for the policy and regulatory-related environment that underpins the Myanmar fertilizer market. In general, provisions of the Law have been effective in stimulating private sector investment and protecting the interests of Myanmar farmers. However, some elements of the Law and existing fragments of implementing regulations are deficient in terms of completeness and clarity based upon

[6] IFDC is currently analyzing fertilizer samples collected across three regions in December 2017 to provide empirical estimates of the quality of fertilizers in Myanmar. This will help shed light on the quality status.

international standards. As a result, application of the Law in accordance with its intended governing role is (to some extent) compromised.

MOALI is dedicated to improving agriculture sector performance in general and (in particular) achieving an orderly transformation of agriculture. Improved application of appropriate agricultural technologies, based upon strengthened public sector systems and expanded private sector investment in input and crop markets, including agribusiness, is targeted. An analysis of the strengths, weaknesses, opportunities, and threats (SWOT analysis) reveals that Myanmar is on a positive track to achieve improved fertilizer use management with attention to balanced fertilizer use achieved through sound recommendations and improved knowledge flows. Expansion of integrated soil fertility management (ISFM) systems with increased farmer use of organic and on-farm waste materials in association with inorganic fertilizers is key to maintaining quality, fertile soils in Myanmar.

The vision of the Soil Fertility and Fertilizer Management Strategy for Myanmar is:

> *Myanmar farmers properly applying ISFM concepts in agricultural production systems with a private sector market-driven fertilizer value chain working with the public sector to provide high-quality products available, accessible, and affordable to farmers to build and maintain soil fertility that will underpin a highly productive and mechanized agriculture sector.*

To achieve the vision, *four key objectives* are established. They are:

- Improve the fertility status of Myanmar soils to support sustainable improvement in agricultural productivity.
- Enhance efficiency and effectiveness in the fertilizer value chain to improve farmers' knowledge of, access to, and use of high-quality fertilizer products.
- Increase farmers' economic returns from fertilizer use.
- Reduce adverse impacts of fertilizer on the natural environment, ecological resources, and climate change.

Achievement of the objectives entails interventions in 10 thematic areas that will contribute to improved soil fertility and fertilizer management effectiveness and efficiency at all stakeholder levels.

Theme 1. Ensure sustainable soil fertility improvement

- ✓ Modernize national soils maps.
- ✓ Develop fertilizer recommendations that are tailored to specific crops and agro-ecological zones.
- ✓ Accelerate provision of soil and plant testing services with an emphasis on improving farmers' use of soil and plant testing.
- ✓ Improve fertilizer use efficiency.
- ✓ Strengthen research programs with an emphasis on ISFM technologies.
- ✓ Strengthen knowledge of the potential impacts of biological materials in yield improvement.
- ✓ Expand and intensify stakeholder collaboration/information-sharing on soil fertility and fertilizer research.

Theme 2. Ensure farmer access to information on soil fertility management

- ✓ Strengthen the public sector's role in technology transfer to farmers throughout Myanmar.
- ✓ Encourage private sector companies to promote technology introduction and knowledge transfer to input dealers and farmers with "common" messaging.
- ✓ Encourage non-governmental organizations (NGOs) to provide farmers with knowledge on soil fertility and fertilizers, either directly or indirectly through input supplier training.
- ✓ Strengthen linkages between agriculture research and extension to further knowledge transfer to farmers.

Theme 3. Emphasize the role of fertilizer use management in climate-smart agriculture

- ✓ Adopt improved soil management practices – ISFM systems – with best management practices for inorganic fertilizers and utilization of organic materials to the maximum extent.
- ✓ Improve water management through irrigation system rehabilitation and upgrades and expanded use of appropriate technologies.

- ✓ Conserve natural resources, which are fundamental to sustainable agricultural production systems – sustaining soil productivity, limiting unnecessary deforestation, and limiting unnecessary crop production on marginal lands.
- ✓ Reduce nutrient losses – improve fertilizer product selection, proper application (placement and timing) of fertilizers, conservation tillage where appropriate.
- ✓ Mitigate impacts of fertilizer use and domestic fertilizer manufacturing and processing on the environment.

Theme 4. Update and fortify the Fertilizer Law and associated implementing regulations

- ✓ Continue the market-oriented policy for fertilizer, relying on private sector investment in fertilizer supply and domestic marketing.
- ✓ Review and strengthen the Fertilizer Law and supporting legal instruments to achieve a modern international standard, comprehensive in scope and clear on all legislative elements.
- ✓ Require registration of all agro-input dealers and sub-dealers as well as general merchandise retailers that engage in fertilizer purchase for resale.
- ✓ Take all appropriate measures to effectively implement and enforce the Fertilizer Law.

Theme 5. Ensure sustainable supply of high-quality fertilizers with improved farmer access

- ✓ Fertilizer supply – continued supply through imports will contribute to supply system efficiencies.
- ✓ Mid- to long-term (2022 and beyond) – monitor global fertilizer market situation and evaluate economic options for fertilizer sector investment vis-à-vis competing opportunities for natural gas demand.
- ✓ Continue private sector-based system with advances in value-added processing to better support balanced fertilizer use.
- ✓ Farmer groups and private sector cooperatives will stimulate development.

Theme 6. Ensure high-quality fertilizers are consistently available in the market

- ✓ Strengthen Land Use Division fertilizer inspection and laboratory analytical capacities, including protocols and methodologies.

- ✓ Improve private sector import procurement systems to mitigate quality risks.

Theme 7. Emphasize monitoring and strategic planning

- ✓ Strengthen the availability of market information on fertilizer supply, farmer use, and prices to support monitoring and strategic planning.
- ✓ Sensitize all stakeholders about fertilizer-related activities, particularly laws and regulations.

Theme 8. Strengthen financial services

- ✓ Improve farmers' access to financing through fortified farmer loan programs administered by Myanmar Agriculture Development Bank (MADB) and Myanmar Livestock and Fisheries Development Bank (MLFDB).
- ✓ Strengthen microfinance opportunities through formal service providers and NGOs to support farmer needs.
- ✓ Extend financial services to agro-input dealers.
- ✓ Continue to support contract farming and farmer groups (including farmer cooperatives).

Theme 9. Fortify institutional and human capacity building at all levels in the fertilizer sector

- ✓ Department of Agricultural Research.
- ✓ Department of Agriculture/Agriculture Extension Division.
- ✓ Department of Agriculture/Land Use Division
- ✓ Yezin Agricultural University.
- ✓ MOALI Agribusiness Information Unit.
- ✓ Agro-input dealer network.
- ✓ Coordination.

Theme 10. Strengthen post-harvest markets and improve farmer access to markets

- ✓ Agribusiness linkages.
- ✓ Infrastructure.
- ✓ Gender empowerment.

The thematic focal areas are interrelated, yielding synergies that will contribute to improved soil nutrient management with increased attention to mitigating risks to adverse environmental consequences of modern agricultural production systems. Importantly, the Soil Fertility and Fertilizer Management Strategy is in proper alignment with the MOALI vision for agriculture. It is complementary to the other agriculture-related strategies.

The rollout of the strategy will require a concerted effort from both the public and private sector and coordination will be a key to its success. Consideration should be given to establishing a coordinating body with public and private sector representation.

Twelve actions are provided to implement the strategy covering technical, industry and policy actions, including the adoption of a site specific integrated soil fertility management system. It is proposed that this start as a pilot project within the five new Regional Research Centers that DAR is establishing jointly with DOA to implement the farming systems research approach.

1. Introduction

"*Myanmar is an agricultural country and the agriculture sector is the back bone of the economy. The agriculture sector including livestock sector contributes 28.6% of GDP, 25.5% of total export earnings in 2015-16 and employs 61.2% of the labor force."*[7] That it has great potential for growth is undisputed. The country has abundant land and water resources, it is close to the very large markets of China and India, and it has a farming community willing to apply modern technology when able. In addition, approximately 500 million inhabitants live in countries that border Myanmar, providing a huge potential market for Myanmar's agricultural goods.

Myanmar's national food security and rural economy both rely heavily on the agriculture sector. The structure of the Myanmar agriculture sector is being transformed with increased emphasis on agribusiness. This transformation will impact the future role of agriculture in the economy. Crop diversification, rapid expansion in use of agricultural technologies (e.g., on-farm mechanization, improved seed, water management systems, high-quality/appropriate fertilizers), land law reform, stronger crop markets, improvements in financial services (targeting agribusiness value chain members and farmers), and infrastructure improvements are targeted to accelerate, yielding synergies that foster rapid transformation. By the end of the current five-year plan (2021/22), the transformation is expected to contribute to an 80% increase in agricultural GDP (value added in agriculture) and a 40% increase in value added in agriculture exports. Among others, the National Agriculture Development Strategy and Investment Plan (ADS) estimates that Myanmar's share of world agriculture exports will increase by 30% during the five-year period.[8]

The Department of Planning (DOP) in the Ministry of Agriculture, Livestock and Irrigation (MOALI) reports that crops were planted on 12 million hectares (ha) in 2015-16, of which rice was grown on 7.21 million ha. Currently, rice is the single most important crop in Myanmar and is grown on more than half of its arable land. Eighty percent of the rice farmers are smallholders, farming less than 5 ha. The Second Short-Term Five-Year Agriculture

[7] Myanmar Agriculture Sector in Brief. 2016. Department of Planning, Ministry of Agriculture, Livestock and Irrigation, The Republic of the Union of Myanmar, Nay Pyi Taw.
[8] *Agricultural Development Strategy and Investment Plan* (draft).

Policies and Strategic Thrusts[9] recognizes that, "*while the agriculture sector contributes 30% of national GDP, both the benefits that are gained from farming as well as the socio-economic status of farmers are extremely low.*" Unpredictable weather changes make farming a high-risk enterprise. Despite this, perhaps to mitigate the risks, farmers seek new technology to achieve higher yields. Application of fertilizer to increase yield has become fundamental to farming in Myanmar. However, managing soil fertility is less understood and, unfortunately, the practices being adopted often are not sustainable and contribute to soil fertility decline and land degradation, which is a spiral into poverty.

2. Background

2.1 Natural Resource Base, Agro-Ecological Zones, and Crop Seasons

Myanmar is endowed with extensive natural resources to support agricultural production. The land area (67.6 million ha) is the largest in continental Southeast Asia. Globally, Myanmar has the 25th largest endowment of cultivated land (arable land and permanent crops), of which only 18% is under cultivation.

Water resources are extensive. There are four major river basins in Myanmar (*Ayeyarwady*, *Chindwin*, *Sittaung*, and *Thanlwin*), and water flows from north to south into the Andaman Sea. The Ayeyarwady River, which flows from the foothills of the Himalaya mountains to the south, is the largest river basin, draining 58% of the territory. It, along with several smaller riverine systems, supports a vast delta area that extends from Myan Aung to the Bay of Bengal and the Andaman Sea. In total, Myanmar's renewable inland water resources are estimated at 19,000 cubic meters per capita, which is ten times the per capita water endowment of China and India (MGI, 2013), and with a current use rate of only 5%.[10]

In addition to its vast agriculture resources, Myanmar possesses extensive reserves of raw materials needed in basic fertilizer manufacture, namely fossil fuels and phosphate rock.[11] Petroleum reserves include 3.2 billion barrels of oil and 7.8 trillion cubic feet of proven natural gas reserves. In 2014, the value of natural gas exports was $5.2 billion out of Myanmar's total exports valued at $12.52 billion.[12] Globally, natural gas is the primary

[9] Agriculture Policy 2016.
[10] Asia Development Bank. 2014. Myanmar: *Unlocking the Potential*, Country Diagnostic Study.
[11] Myanmar has no known deposits of potash.
[12] Fong-Sam, Y. 2014. *The Mineral Industry of Burma*. U.S. Geological Survey Minerals Yearbook, 2014.

feedstock for commercial-scale nitrogen fertilizer manufacture. Phosphate reserves have been identified near Mandalay, Mogok, and Nyaungcho. Myanmar is also endowed with gypsum, dolomite, and 60,680 million tons of limestone across 468 deposits.[13]

There are four diverse agro-ecological zones (AEZs) in Myanmar: (1) Hill and Mountainous, (2) Central Dry, (3) Delta, and (4) Coastal. Some classifications list three AEZs, combining the Delta and Coastal zones.[14] The ADS lists five AEZs by separating the Yangon-Bago Zone from the Delta.

Myanmar has two main climatic regions. The tropical south accounts for about two-thirds of the country, and the subtropical and temperate north accounts for about one-third. There are two main seasons. The dry season extends from mid-October to mid-May, and the monsoon season starts in mid-May and continues through October. The dry season includes a cool-dry season (mid-October to February) and a hot-dry season (March to mid-May). Therefore, the agriculture sector has large potential for sustained growth because of its agro-climatic conditions and rich endowment of resources in Myanmar.

2.2 National Agriculture Policy

The 2016 Agriculture Policy, under the five-year plan,[15] includes the MOALI vision for the agriculture sector: *An inclusive, competitive, food- and nutrition-secured and sustainable agricultural system contributing to the socio-economic well-being of farmers and rural people and further development of the national economy*. The vision is broad. It encompasses key elements and indicators of progress that influence Myanmar's prioritization of strategic actions. As illustrated in Table 1, the key elements in the vision are interrelated and have direct relevance to the fertilizer sector.

[13] Ohn, Kyaw Kyaw. 2015. *Geology and Mineral Resources of Myanmar* by Kyaw Kyaw Ohn. Department of Geological Survey and Mineral Exploration, Ministry of Mines.
[14] Ministry of Environmental Conservation and Forestry. 2012. *Myanmar's National Adaptation Program of Action (NAPA) to Climate Change*. <http://unfccc.int/resource/docs/napa/mmr01.pdf>
[15] *Five-Year Plan (2016/17 – 2020/21)*.

Table 1. National Agriculture Policy of Myanmar – Vision Elements

Vision Elements	Indicators
Inclusion	1. Marginal/landless male farmers' income 2. Marginal/landless female farmers' income 3. Rural poverty rate
Competitiveness	1. Investment in agri-food sector 2. Value of agriculture exports 3. Value added in agriculture 4. Share of Myanmar agriculture exports in world agriculture exports
Food/Nutrition Security	1. Stunting among children under 5 2. Underweight among children under 5 3. Wasting among children under 5 4. Women of reproductive age with chronic energy deficiency
Sustainable	1. Land productivity 2. Labor productivity 3. Adoption of good agricultural practices (GAPs) 4. Water use efficiency 5. Soil fertility
Well-Being	1. Smallholder male farmers' income 2. Smallholder female farmers' income

The ADS was prepared to support this policy. The ADS is, in effect, a guide that identifies specific actions linked to targeted outcomes, outputs, and results indicators. The ADS includes the specific government entity designated to have primary responsibility for the specific outcomes and outputs. It also includes the budgetary amount allocated for each outcome and output.

3. Myanmar Soils and Management Essentials to Achieve Improved Yields (Quality/Quantity) on a Sustainable Basis

Wikipedia describes soil fertility as "*the ability of a soil to sustain agricultural plant growth, i.e., to provide plant habitat and result in sustained and consistent yields of high quality*." It describes fertilizer as "*any material of natural or synthetic origin (other than liming materials) that is applied to soils or to plant tissues to supply one or more plant nutrients essential to the growth of plants.*" Soil fertility and fertilizer management are interrelated to sustain plant growth. Fertile soils are required for high yields and high quality of crops, and fertilizers are a means to sustain fertile soils. Soils supply the essential elements for plant growth and plant nutrition, for animal nutrition, and for human nutrition; fertilizer is needed

to supplement soil nutrients, lest yield and quality of produce decline and the products cannot sustain human health. Soils are perhaps the most underrated and yet most valuable natural resource and are essential for productive and sustainable agriculture. There is a tendency for decision-makers, donors, and even farmers to take soil fertility for granted as an inexhaustible resource. However, history has shown this to be a mistake.

The Land Use Division (LUD), Department of Agriculture (DOA), MOALI, is entrusted with the responsibility of overseeing all aspects of agricultural land use for agricultural purposes. This includes characterization and monitoring of the soil status in Myanmar.

3.1 Soil Characteristics

Most of the soils in Myanmar suffer from improper land use practices during the past several decades. These include nutrient mining, leaching, improper land preparation, and inadequate erosion control. Much of the agricultural land in Myanmar is vulnerable since agriculture has intensified and poor management is reducing soil fertility. Land degradation can be attributed to improper land use, misguided land management leading to unproductive farming, and pollution in downstream water bodies.

Soil classification in Myanmar has evolved from aerial photo interpretations to a Russian system and finally its modification to correlate the Rosanov system with the FAO/UNESCO classification system.[16] The LUD continues to map soils to increase the scale from 1:2,500,000 to 1:1,000,000, but at this scale it is still not large enough for agriculture. However, a soil sampling intensity of one sample every 50 acres will provide a better database on which to manage soil fertility.

The DOA/LUD describes 24 soil types in Myanmar.[17] Agriculturally important soils in terms of key crops and the area under cultivation are:

1. Alluvial soils (Fluvisol) are found in the river plains, deltas, former lakes, and coastal areas. These are young soils with neutral pH and inherently fertile.
2. Meadow or paddy soils (Gleysol), comprising meadow gley soils (Gleysol), meadow alluvial (Gleysol Fluvic), meadow swampy (Humic Gleysol), and meadow carbonate

[16] *Soil Types and Characteristics of Myanmar*, Land Use Division, Ministry of Agriculture and Irrigation, The Republic of the Union of Myanmar.
[17] Shein, Htein Aung. 2015. *The Soil Types and Characteristics of Myanmar*. DOA, Ministry of Agriculture and Irrigation.

(Calcaric Gleysol) are found in different parts of Myanmar in river plains, delta and low coastal plains, and valleys. They can be utilized for groundnut, pulses, sesame, sunflower, jute, sugarcane, and vegetables, in addition to rice cultivation. Together, the alluvial and meadow soils occupy about 50% of cultivated land.

3. Red Brown Savanna soils (Luvisol) occur in the undulating relief of the hill slopes and low uplands. The soil pH ranges from 7 to 8. These soils are the most important land resources of the Central Dry Zone. Most of the areas are plowed and cultivated. However, large areas are in great danger of soil degradation due to continuous cropping for many years without soil amelioration.
4. Dark compact soils (Vertisol) occur in the Central Dry Zone in the level plains of Sagaing, Mandalay, and Magway divisions. They occur in the lowlands near the rivers and the broad depression in the areas of Red Brown Savanna soils. These are the best soils for irrigated farming. They are the second most important soil for agriculture in the Central Dry Zone. The soil pH ranges from 7 to 9 (alkaline and calcareous).
5. Red Earths and Yellow Earths (Acrisol) are the most dominating soils of Shan Plateau and the northern mountainous region at an elevation of more than 3,000 feet above sea level. The Yellow Earths occur on the lower level slopes in the Shan Plateau, occupying a relatively small area. The Red Earths have a very deep profile with texture varying from sandy and silty to silty clay loam and with good structure and pH ranging from 6 to 7. However, the Yellow Earths soils are more acidic and have a higher percentage of clay. The Red Earths are the typical soils for agriculture in Shan State.

3.2 Soil Fertility, Plant Nutrition, and Human Health

Fertile and productive soils are vital components of stable societies, because they ensure growth of plants needed for food, fiber, animal feed and forage, industrial products, and energy. Soil fertility integrates the basic principles of soil biology, soil chemistry, and soil physics to develop the practices needed to manage nutrients in a profitable, sustainable, and environmentally sound manner. Soils differ widely in their ability to meet nutrient requirements of plants; most have only moderate natural soil fertility.

All plants need at least 17 essential elements to complete their life cycle. In addition to carbon (C), hydrogen (H), and oxygen (O), there are 14 elements derived from soils that are essential for plant growth. These are called plant or crop nutrients. Four additional elements

(including cobalt [Co], sodium [Na], silicon [Si], and barium [Ba]) are beneficial for proper development of some plants. The plant nutrients are divided into three subgroups:

1. Macro- or primary nutrients: nitrogen (N), phosphorus (P), and potassium (K). Plants require these nutrients in higher quantities. They are important for many critical functions (Table 2).
2. Major or secondary nutrients: calcium (Ca), magnesium (Mg), and sulfur (S). Most plants require as much S as they do P.
3. Micronutrients (or trace elements): chlorine (Cl), iron (Fe), manganese (Mn), boron (B), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni). Plants require much smaller quantities of micronutrients, but they are still important for plant growth.

The role of the nutrients, forms of uptake, and concentration in soils and plants are summarized in Table 2. As evident from Table 2, balanced nutrition, the availability of all essential nutrients, is an important aspect of sustainable agriculture. This is because:

1. Crops need all nutrients; however, excessive quantities of micronutrients can be toxic.
2. Application of a single nutrient, such as N, can increase yield, but the need for other nutrients also increases, and eventually yields can suffer. Based on the "law of the minimum,"[18] with adequate application of N, another factor – light, water, temperature, disease, or lack of other nutrients – becomes limiting.
3. Uptake of nutrients, such as K, Mg, Ca, P, and Zn, depends on their ratio in the soil solution; for example, too muck K can reduce Mg uptake.
4. Loss of nutrients, particularly N, from the soil increases if deficiency of other nutrients results in reduced plant demand for N.

Hence, balanced nutrition improves plants' tolerance to stresses, reduces losses of nutrients through leaching, runoff, and emissions, and results in healthy plants and roots. The plants are not affected by whether the nutrients come from inorganic fertilizer solutions, soil organic matter mineralization, or decomposition of manures, roots, or crop residues. Plant roots take up the nutrients in their ionic forms, such as NO_3^-, NH_4^+, H_2PO^-, K^+, Ca^{2+}, etc.

The availability of nutrients from soils is affected by soil water, the weathering process of parent material, deposition and erosion of sediments, mineralization of N, P, and S from

[18] Liebig's law of the minimum states that growth is dictated not by total resources available but by the scarcest resource (limiting factor).

organic matter and immobilization by microbes, adsorption/desorption by organic and inorganic particulates, and binding to humic compounds. The presence of plants and exudates from roots also influences the nutrient supply from soils. With fertile soils recently brought into agriculture, all plant nutrients could be directly supplied by the soil. To achieve production targets, more nutrients are usually required than can be supplied by the soil. High crop yields mean greater depletion of soil nutrient supplies, which eventually must be balanced by increased nutrient input to maintain the fertile soils. If the nutrients removed by crop uptake are not replaced, the soil is gradually mined of nutrients, resulting in poor yields with low nutrient content (protein and minerals). Unfortunately, soil nutrient deficiency, resulting in imbalanced crop nutrition and poor yields, impacts animal nutrition and human nutrition.

In Myanmar, 35-53% of the rural population suffers from inadequate food, nutrition, and essential non-food items. Micronutrient deficiencies account for 4-6% of all deaths of children under five years old.[19] In general, Southeast Asia has a very high incidence of malnutrition (Table 3), particularly in Myanmar where a high percentage of the population has low Zn dietary intake.[20] Improving the food and nutrition security of children and women is one of the vision elements of the National Agriculture Policy of Myanmar.

[19] *Myanmar Climate-Smart Agriculture Strategy.*
[20] Wessells, R.K., and K.H. Brown. 2012. "Estimating the Global Prevalence of Zinc Deficiency: Results Based on Zinc Availability in National Food Supplies and the Prevalence of Stunting," *PLoS One* 7:e50568.

Table 2. Plant Nutrients, Classification, Form of Uptake, Functions, and Concentrations in Soils and Plants

Nutrient	Taken Up As	Important Functions	Approximate Concentration in Soils	Approximate Concentration in Plants
Primary				
N	NH_4^+ NO_3^-	Components of cell compounds – proteins, chlorophyll, and genes	0.3-1%	1.5%
P	HPO_4^{2-} $H_2PO_4^-$	Constituents of genes, energy transfer, and protein metabolism	0.02-0.5%	0.2%
K	K+	Osmotic and ionic regulations, enzyme functions in carbohydrate and protein metabolism	0.05-3.8%	1%
Secondary				
Ca	Ca^{2+}	Cell division and maintenance of membrane integrity	0.7+%	0.5%
Mg	Mg^{2+}	Component of chlorophyll and a factor in many enzymatic reactions	0.6+%	0.2%
S	SO_4^{2-} HSO_4^-	Constituents of proteins, amino acids, and vitamins. Production of plant oils	30-600 ppm	0.1-0.2%
Micronutrients				
Fe	Fe^{2+}	Component of many enzymes – cytochromes (respiratory enzymes) and ferredoxins involved in photosynthesis and N fixation	1-6%	100 ppm
Zn	Zn^{2+}	Enzyme systems for synthesis of nucleic acids and metabolism of auxin	1-130 ppm	20 ppm
Mn	Mn^{2+}	Several enzymes including those for photosynthesis	120-6,000 ppm	50 ppm
Cu	Cu^{2+}	Component of enzymes, photosynthesis, and grain production	1-100 ppm	6 ppm
B	H_3BO_3 $H_2BO_3^-$	Structural role in cell walls, membrane function, stimulation or inhibition of specific metabolic pathway, and involvement in flowering and fruiting	4-100 ppm	20 ppm
Cl	Cl^-	Photosynthesis and osmoregulation of plants growing on saline soils	7- >50 ppm	35-2,000 ppm
Mo	MoO_4^{2-} $HMoO_4^-$	Assimilation of N in plants (NO_3^- to NH_4^+). N fixation and chlorophyll	0.1-40 ppm	0.1 ppm, 1.6 ppm for legumes
Ni	Ni^{2+}	Constituent of urease enzyme in legumes	1-40 ppm	0.1 ppm

Source: UNIDO/IFDC. 1998. *Fertilizer Manual*. Kluwer Academic Publishers, Netherlands; Marschner, H. 1995. *Mineral Nutrition of Higher Plants*, 2nd edition, Academic Press, London.

Table 3. Micronutrient Malnutrition as a Percentage Prevalence

Region	Zn	Fe	I	Vitamin A
North America	8-11	18-29	11	2-16
Latin America	13-37	18-29	11	2-16
Europe	6-16	19-25	52	12-20
Sub-Saharan Africa	13-43	48-66	44	14-44
Southeast Asia	27-39	46-66	30	17-50
South Asia	18-36			
Global	**10-32**	**30-47**	**32**	**15-33**

Sources: Bouis, H., E. Boy-Gallego, and J.V. Meenakshi. 2012. "Micronutrient Malnutrition: Causes, Prevalence, Consequences, and Interventions," IN *Fertilizing Crops to Improve Human Health: A Scientific Review*, *Volume 1. Food and Nutrition Security*, pp. 29-64, T. Bruulsema, P. Heffer, R. Welch, I. Cakmak, and K. Moran (Eds.), IFA, Paris, France.

3.3 Soil Nutrient Removal Through Cropping

The amounts of soil nutrients removed from fields by cropping depend on expected yields, crop type, and parts of the crop removed (Table 4). Grain yields of rice and maize range from 1.5 to more than 7 tons per hectare (t ha^{-1}) in Myanmar, while yields of sugarcane, on average, are more than 60 t ha^{-1}. Therefore, for example, if all rice straw residue is recycled, then rice grain removes about 65% of total N, 85% of total P, but only 10% of total K. The nutrients in crop residues, depending on the residue management practice, become partly available to the subsequent crops after mineralization; however, losses do occur. For Myanmar farmers who grow two to three crops per season, there is not enough time for residue incorporation and decomposition, so many farmers burn the residue to facilitate land preparation. Some farmers also feed rice straw to their cattle and buffalo. Some farmers also sell rice straw to mushroom growers. Mechanization that promotes zero or minimum tillage should lead to better residue and nutrient management.

Table 4. Area Sown, Yield, Production, and Nutrient Removal by Harvested Component and All Parts for Key Crops in Myanmar for 2015/2016

Crops	Sown Area ('000 ha)	Yield (t ha^{-1})	Production ('000 t)	Nutrient Removed by Harvest (t)			Total Nutrient Removed by Harvest plus Straw (t)		
				N	P	K	N	P	K
Rice	7,212	3.6	26,210	382,666	68,670	68,146	581,862	81,251	686,702
Maize	472	3.7	1,749	31,482	7,696	10,162	39,877	9,619	48,972
Pulses	4,382	1.0	4,225	257,656	22,001	160,973	325,325	26,026	176,183
Groundnut	955	1.6	1,518	58,636	5,291	8,943	87,080	8,082	38,088
Sesame	1,530	0.5	827	33,131	6,898	33,907	42,177	7,443	35,561
Wheat	96	1.9	179	3,759	752	823	5,119	877	4,117
Cotton	291	1.8	521	28,287	3,519	4,205	31,521	3,751	15,630
Sugarcane	162	63.7	10,305	5,925	1,395	15,385	23,341	6,338	79,812
Total				**801,543**	**116,222**	**302,544**	**1,136,302**	**143,387**	**1,085,065**

Sources: Department of Agricultural Land Management and Statistics (DALMS). 2017. Production Data, 2017; USDA, 2017: Crop Nutrient Tool," Natural Resources Conservation Service, https://plants.usda.gov/npk/main; IFA, 1992, *World Fertilizer Use Manual,* International Fertilizer Association, Paris, France.

The assumption that nutrient removal increases linearly with yield is reasonable for Myanmar since the average yields shown in Table 4 are low. To maintain sustainable and productive agricultural systems, all nutrients removed by crop harvest and by residue and nutrient losses due to erosion/runoff, leaching, and emissions must be (at the very least) replaced. In the case of pulses and legumes, attention must be paid to factors that influence biological fixation of nitrogen. As evident from Table 4, more than 0.3 million t of N are removed with the harvest of pulses and groundnut, and the main sources for this N are biological N fixation and the indigenous soil N supply.

3.4 Sources for Replacement of Crop Nutrients

Continuous improvement in food production requires sustainable management of soils and fertilizers. If not replenished, the soil's supply of nutrients can become depleted. The main nutrient sources are: (1) soil reserves, including soil organic matter; (2) decomposing plant residue (roots and straw); (3) animal manure; (4) irrigation and floodwater; (5) biological N fixation; (6) organic or natural fertilizers; (7) biofertilizers; and (8) chemical fertilizers. The first four depend on farming systems and farm management. Pulses, one of the major crops in Myanmar, take advantage of biological N fixation in meeting the crop's N requirement.

However, for effective biological N fixation, nutrients such as P, Ca, S, Mo, Ni, and Co are needed. The remaining three are fertilizers that fall under the Fertilizer Law.

3.4.1 Organic Fertilizers

Organic, or natural, fertilizers can be useful as both a soil amendment and a supply of nutrients. Soil organic matter not only provides a source of crop nutrients, but also supports soil ecosystems that improve soil physical characteristics, increase soil water retention, and help to promote the release and crop uptake of nutrients. Given this critical role, soil organic matter is essential to sustainable agriculture production systems.

Definition of Fertilizer in the Fertilizer Law

Fertilizer means chemical fertilizer, biofertilizer, or natural fertilizer, which consists of material that can help ensure chemical change in the soil or other means for plant nutrition for the growth of fruits, flowers, crops, and plants. It does not include any natural fertilizer made by any grower for use on his or her own farm.

Chemical fertilizer means the fertilizer prepared with chemicals using any means and not being naturally made or composed. It also includes mineral fertilizer or organic and inorganic chemical fertilizer produced by a factory.

Biofertilizer means the fertilizer produced by multiplying beneficial organisms, such as bacteria, fungi, etc., for the growth of plants.

Natural fertilizer means the remains, waste, or byproducts of fauna and flora obtained and prepared through decomposition.

Since much soil organic matter is a waste product, it can sometimes be cheaply available, especially if used near where it is produced. If waste material of any kind is bought by the farmer, it must be comparatively cheap, have no detrimental or toxic effect, and be profitable. Some waste material contains a high level of heavy metal content. Use of organic fertilizers usually requires handling and transporting large volumes of material to obtain relatively low levels of nutrients, so it is best to use these on fields near the source. Processed organic fertilizers generally require mechanical and chemical preparation (i.e., they must be dried, ground, mixed, granulated, neutralized, complemented by the addition of nutrients, and free of pathogenic germs). Technologies to enrich organic fertilizers with chemical fertilizers are available, and at least one Myanmar company is producing and marketing enriched organic fertilizers.[21]

[21] Supreme BioTech Company Limited.

Table 5. Types of Organic Fertilizers

Type	Source
Naturally occurring materials	Peat
Farm wastes	Crop residues
	Animal manures
	Compost
	Green manures
Residues from processing plant products	Fibers, pressed cakes (from oilseeds), grinds
	Wood materials
	Bagasse (sugar industry)
	Byproducts from the starch industry
	Seaweed extracts
Residues from processing animal products	Blood, horn, and bone meal
	Byproducts from the fish processing industry
	Leather dust, feathers
Urban wastes	Composted household refuse
	Sewage sludge

3.4.2 Biofertilizers

Biofertilizers are microbial inoculants or organic growth stimulators that enhance crop yield and/or produce quality. The key role of biofertilizers is to improve accessibility of plant nutrients through: (1) increased biological N fixation, (2) solubilization of bound nutrients, (3) increased root distribution system, (4) biological control of plant pathogens, and (5) enhanced crop resistance to diseases and pests.

The inoculation of soils or legume seeds with *Rhizobium* bacteria is a well-established practice in Myanmar supported by the Department of Agricultural Research (DAR). However, there is limited rhizobium research and inoculum production, which should link to soil fertility and fertilizer management. Other bacteria and fungi, such as *Azospirillium* and *Azotobacter* for N-fixing, P-solubilizing bacteria, and vascular arbuscular mycorrhizae (VAM) are marketed as soil inoculants or combined with organic or natural fertilizers to improve the availability of nutrients. The production of quality soil inoculants, good techniques, and quality raw materials are necessary, and care must be taken to ensure quality of the products all the way through the value chain system. Some bacteria and fungi are also used for plant protection, such as *Bacillius thuringiensis* as an insecticide and *Trichoderma harzianum* against root pathogens. Organic stimulants containing humic acids, extracts of seaweeds and plants, and amino acids are applied on crops in small amounts (1-10 kg ha^{-1}). Locally available biofertilizers in Myanmar are VAM, *Rhizobium*, neem extracts, *Lecanicillium (Verticillium) lecanii* and *Beauveria bassiana* extracts for biological control of

insects, seaweed extracts, amino acids, and humic acid growth stimulators. In addition, artificial tertiary amine bioregulators, such as diethyl aminoethyl hexanoate (DTA6) as an additive to urea, are available in Myanmar. Above-optimal application rates of bioregulators can negatively impact crop growth; thus, correctly reporting the concentration of such products on the fertilizer bags, along with the application rate, is critically important.

3.4.3 Chemical Fertilizers

Chemical fertilizers are also referred to as inorganic or mineral fertilizers. They are derived from basic raw materials, namely atmospheric nitrogen, phosphate rock, and potassium salts, that are naturally occurring.[22] Complex chemical processes enable the manufacture of fertilizers that contain various amounts of the elements nitrogen, phosphorus, and potassium essential to crop production. Due to technological advances in the past century, mineral fertilizers are often quite high in analysis (e.g., nutrient content of solid fertilizers up to 64-66% by weight) because of manufacturing processes involving chemical reactions under high pressure and extreme temperatures. High analysis fertilizer products allow for economic efficiencies in manufacture and transport costs per unit of nutrient contained in the fertilizer.

Globally, mineral fertilizers have driven much of the improvement in agricultural yields and (along with improved seeds, crop management systems, and water management) are responsible for feeding nearly half of the world's population.[23] Mineral fertilizers are the most convenient source of plant nutrients with negligible moisture content and an indefinite shelf-life when properly stored. The extent to which world food production depends on fertilizer use will inevitably increase in the future. Without fertilizers, the world would produce only about half as much staple food, and more marginal and forested lands would need to be put into production. Globally, of the 181 million t of nutrients used for crop production in 2013, 70% were used in developing countries and 30% in developed countries. China and India, the two most populous countries in the world, consumed 43% of the total amount of nutrients applied through fertilizers. In Myanmar, fertilizer use has been identified as a major contributing factor influencing rice production.[24] The introduction of high-yielding

[22] Naturally occurring potassium nitrate (saltpeter) and guano are available in some limited quantities (for example) in Chile and the Christmas Islands, respectively; their contribution to the global fertilizer supply is very low.
[23] Erisman, J.W., M.A. Sutton, J. Galloway, Z. Klimont, and W. Winiwarter. 2008. "How a Century of Ammonia Synthesis Has Changed the World," *Nature Geoscience*, 1:636-639.
[24] Naing, T.A.A., A.J. Kingsbury, A. Buerkert, and M.R. Finckh. 2008. "A Survey of Myanmar Rice Production and Constraints," *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 109:151-168.

varieties, combined with NPK application, has resulted in rice yields of 7 t ha^{-1}, compared with less than 3 t ha^{-1} in non-fertilized controls.[25]

A large selection of mineral fertilizers (more than 40 grades or nutrient formulations) for soil and foliar applications is available in Myanmar (Table 6).[26] Available fertilizers include those that supply a single nutrient ("straight fertilizers") and others that supply two or more nutrients (i.e., "complex/compound" and bulk blend fertilizers).

Table 6. Chemical Fertilizers in Myanmar

Type of Fertilizer	Name and Nutrient Content (N-P_2O_5-K)
Straight	Urea (46% N), TSP (46% P_2O_5), SSP (20% P_2O_5), MOP[a] (60% K_2O)
Complex	Ammonium sulfate (21% N, 24% S), calcium ammonium nitrate (21-27% N, 8% Ca), Sulfate of potash (SOP - 50% K_2O, 18% S), Diammonium phosphate (DAP - 18% N, 46% P_2O_5), gypsum (20% Ca, 18% S)
	NPK: 30-10-10, 25-7-7, 21-11-21, 20-20-10, 20-10-20, 20-12-12, 19-11-22 (100% water soluble), 16-16-16, 16-16-8, 15-15-15, 15-10-5, 15-7-8, 15-5-5, 13-5-7, 12-13-0, 10-10-5, 9-25-25, 9-9-19, 5-5-5
	NPKplus: 20-10-5-7S+ME,[b] 19-9-19-1S+2.1% Ca, 18-4-5-15S, 16-16-16 + 25Ca + 0.4Mg + 0.02B, 16-16-8-13S+ME,[b] 15-15-30+ME[b] (soluble), 15-15-15-7S+ME,[b] 15-15-15+ME,[b] 15-10-20+4Mg+ME,[b] 15-5-20-5S+ME,[b] 13-13-21+ME[b]
With additives	Urea + gypsum (40% N, 2.2% S, 3.8% Ca)
	Urea (44% N) with rice herbicide
	Urea (44% N) with growth regulators for vegetative and grain growth (nitroguaiacol sodium salt and p-nitrophenol sodium salt, diethyl aminoethyl hexanoate - DTA6), benzoic acid for pest control
	Ammonium sulfate plus rice herbicide (pyrazosulfuron-ethyl), ammonium sulfate plus DTA6
Foliar	Multi N-P-K, Multi-Fert, Super-K, Quick-Mg

a. MOP also supplies Cl, an essential nutrient.
b. ME = micronutrients.

Cost is one of the major factors in farmers' choice of fertilizer product. For example, low analysis fertilizers are generally marketed to rice, pulse, groundnut, and sesame farmers because they are less expensive in terms of product price. However, in most cases, the low

[25] Matsuda, M. 2011. "Intensification Level of Rice Farming in Myanmar: Implication for Its Sustainable Development," *Environment, Development and Sustainability*, 13:51-64.
[26] Note: More than 3,000 fertilizer products are registered. The number is inflated because it may include the same fertilizer formulation from different suppliers and importers or even include the same fertilizers packaged in different bag sizes.

analysis products are not the lowest cost fertilizers in terms of the cost per unit of nutrient that is supplied by the products.

4. Roles and Responsibilities for Soil Fertility and Fertilizer Management in Myanmar

A positive aspect of soil fertility and fertilizer management in Myanmar is the active public and private sectors. The various functions and responsibilities (of the public and private sector), and where they combine to yield mutual impacts and benefits, are shown in Table 7.

Table 7. Role of Public and Private Sectors in Myanmar Fertilizer Market

Function/Responsibility	Public Sector	Private Sector
Fertilizer policy/legal and regulatory system, including product and business registration/ licensing	X	
Fertilizer quality self-regulation		X
Domestic fertilizer manufacture/processing	X	X
Fertilizer import/wholesale activities		X
Retail/dealer network development		X
Fertilizer pricing		X
Fertilizer product mix management		X
Financial services: Marketing channel members		X
Financial services: Farmers	X	X
Technology transfer/farmer education	X	X
Fertilizer recommendations/soil testing	X	X
Fertilizer product registration/quality control	X	X

As indicated, policy and regulatory functions are under the government purview. After a fertilizer legal and regulatory framework is established and efficiently implemented by the government, a culture of good fertilizer quality driven by a self-regulated private sector becomes prevalent. This has been the experience of the fertilizer markets of developed countries after adoption of regulatory systems in the early 20th century. Commercial activities in the fertilizer market are primarily private sector functions. And in the case of fertilizer research and development and technology transfer, both the public and private sectors play key and complementary roles.

4.1 Public Sector

DAR is responsible for soil and crop research (food, fiber, and biofuels). DOA, through its LUD, is responsible for overseeing all aspects of land use for agricultural purposes. This includes:

- Exploration of soil maps: land type maps, soil maps, agro-ecological zone maps, and land degradation maps.
- Reclamation of problem soils, soil conservation, fertilizer recommendations for various crops, balanced fertilizer application, and ISFM.
- Soil analyses.
- Soil fertility and fertilizer management research and development.

In addition to its important functions in agricultural land use and soil fertility management, the LUD is also responsible for fertilizer product and business registration as well as post-registration surveillance (including quality inspection and product sampling and analysis) and transfer of soil and nutrient management technologies to farmers, including agriculture extension staff and farmer training.

LUD's Yangon laboratory is well-positioned to analyze all soil nutrients (including heavy metals) and fertilizers. The soils laboratory at Mandalay can analyze most nutrients, including some micronutrients. However, both of these laboratories have a low sample analysis turnaround (no more than 10 per day) primarily due to equipment limitations. Five regional labs (Bago, Kachin, Kayah, Magway, and Shan) are limited to analyses of soil pH and macronutrients N, P, and K. The Yangon lab is responsible for verifying results from the regional labs. The ongoing soil characterization and soil mapping effort, with sampling at every 50 acres, will improve resolution and the quality of soil data for site-specific recommendations, modeling, and remote-sensing applications. The ongoing training of scientists and addition of modern laboratory equipment at the Yangon lab are steps in the right direction. In the regional DOA and DAR offices and labs, more well-trained researchers and technicians are needed for the collection of representative soil samples from target regions and farmers' fields and translation of soil analyses results into recommendations. In the township offices, limited funding is a key constraint that limits what the extension staff can accomplish. Staff, particularly at regional research centers, have limited or no funds to conduct research, seldom have opportunities for refresher training, and therefore lack

motivation. Such constraints should be considered a serious threat, particularly given that Myanmar has one of the lowest numbers of trained researchers at the post-graduate level in Asia.[27]

Yezin Agricultural University (YAU) within the MOALI is responsible for providing highly qualified agricultural scientists needed for development of the agriculture sector. YAU has also been very effective in technical training on modern methods of agriculture and on practical training of students who wish to engage in scientific farming through cooperatives or private enterprises. In addition, 14 state agricultural institutions offer a diploma in agriculture. The Central Agriculture Research and Training Centre (CARTC) within DOA provides training for extension staff on agronomy and economics of production technology of rice, maize, vegetables, and fruits. However, all of these centers of higher education and training in agriculture and soil research need to significantly modernize and transform their facilities, update and revise agriculture and soil courses with more emphasis on quantitative methodology, and emphasize farming as a business that requires proper bookkeeping, monitoring, and evaluation.

4.2 Private Sector

While the private sector performs essentially all commercial functions in the fertilizer market with the exception of fertilizer manufacture, there is an overlap with the public sector in research and extension. With many complementary roles, the main difference is that private sector interests are more central to the business interests of individual companies, e.g., to introduce and expand market share for a particular brand or product that will increase company revenues and profits. Public sector efforts in research and extension, however, are directed at promoting improved use of appropriate technologies that will benefit the country through improved agriculture sector performance, agribusiness development, and rural incomes.

To some extent, the void in public sector research (particularly in promotion of soil testing to generate meaningful soil data for recommendations based on balanced crop nutrient requirements) is being met by private companies. Privately owned laboratories are engaged in

[27] Japan International Cooperation Agency (JICA). 2013. "Data Collection Survey on Agriculture Sector in the Republic of Union of Myanmar," Final Report.

soil analyses and have the capacity to analyze fertilizers for macro- and secondary nutrients.[28] Those that have invested in their own laboratory facilities have done so as a key component in their fertilizer quality control and assurance programs.

The Awba Group, in collaboration with SoilCares (Netherlands), is introducing fast, infield, affordable soil-based fertilizer recommendations in Myanmar. The calibration of sensor technology for soil testing services should be a high priority. Joint partnership between private and public sector will help ensure confidence in sensor-based technology, its recommendations, and greater acceptability.

All major fertilizer companies in Myanmar are engaged in research field trials and on-farm demonstrations of fertilizer products to determine crop- and zone-specific fertilizer recommendations. Importantly, the private sector approach to fertilizer-related knowledge transfer is typically through fertilizer dealers.

4.3 International Organizations and Non-Governmental Organizations

International organizations, research institutions, and universities (Australia, Germany, India, Japan, Korea, New Zealand, Philippines, Thailand, United Kingdom, and USA) have played a vital role in training scientists and promoting agricultural research in Myanmar. The exchange of information, knowledge gained, and the interactions in Myanmar and abroad have been rewarding for all parties.

Traditionally, most research efforts have been on commodity crops, food security, and smallholder farmers. Recent research approaches focus on: (1) more engagement with DAR, DOA, and YAU; (2) soil and water quality; (3) improved nutrient use efficiency; and (4) site-specific recommendations for balanced nutrition. For example, the Livelihoods and Food Security Trust Fund (LIFT) project, implemented by the International Fertilizer Development Center (IFDC), in the Central Dry Zone has been training private sector service providers in the use and sale of simple soil test kits for farm-level fertilizer recommendations while increasing farmer awareness of the value of balanced recommendations.

[28] Win, Zaw Min. 2017. "Challenges in Setting Up Private Fertilizer Quality Assurance Laboratory in Myanmar," Myanmar Awba Group, prepared for the National Conference on Soil Fertility and Fertilizer Management in Myanmar.

Of the 56 NGOs in Myanmar, the majority conduct activities related to food security and livelihood improvement. Many NGOs offer activities for improving agricultural productivity, consolidating irrigation infrastructure, providing micro-credits, etc.[29] One of the NGOs (Proximity Designs) also promotes the use of soil test kits for fertilizer recommendations.

4.4 Coordination

The Myanmar Fertilizer, Seed and Pesticide Entrepreneurs Association serves to coordinate the private sector, and the government has its overarching policies. Nevertheless, there is a need for a platform that will coordinate the various sector players. There are numerous stakeholders, including smallholder farmers and their associations, analytical service providers, national and international research and extension organizations, fertilizer manufacturers and blenders, those involved in fertilizer distribution, sales and infrastructure, market information service providers, fertilizer policymakers, national regulatory bodies, financers, mapping and GIS experts, and donors. All possess unique experience and knowledge that relate to their primary functions. Yet, many stakeholders are siloed, sometimes not appreciating skills outside of their organization or expertise, and occasionally in competition with one another for business opportunities or funding. Increased interaction between the multiple stakeholders will accelerate implementation of strategic objectives and is ultimately to the benefit of all. Mechanisms of collaboration need to be established in the form of stakeholder platforms at various levels.

5. The Fertilizer Market in Myanmar

There is a large degree of uncertainty associated with fertilizer use data for Myanmar, with 100,000 t reported in 2008-2010,[30] 299,000 t in 2010-2011,[31] and 1.2-1.4 million t in 2014.[32] It is estimated that Myanmar farmers used about 1.5-1.6 million t of fertilizers in 2016.

[29] Directory of International Non-Governmental Organizations in Myanmar, 2014.
[30] Lwin, H.Y., T. Myint, S. Than, N.M. Aung, C.C. San, and T. Htut. 2013. *Role of Fertilizer Policy in Transforming Agriculture of Myanmar*, Department of Agricultural Economics, Yezin Agricultural University, Yezin, Nay Pyi Taw, Myanmar.
[31] Japan International Cooperation Agency (JICA). 2013. "Data Collection Survey on Agriculture Sector in the Republic of the Union of Myanmar," Final Report.
[32] Gregory, D.I., U.T.M. Shwe, and N. Oo. 2014. "Myanmar Fertilizer Policy Evaluation," International Fertilizer Development Center, Muscle Shoals, Alabama USA.

5.1 Fertilizer Demand

Reliable time series data on the Myanmar fertilizer market are unavailable. Estimates of farmers' use of fertilizers are based on (1) prior country fertilizer studies, (2) discussions with government and private sector officials, and (3) calculations of assumed fertilizer consumption.[33] Fertilizer supply estimates are based on unpublished fertilizer import data (available through the Ministry of Commerce) and unpublished fertilizer production data (available through the Ministry of Electricity and Energy).

Based on estimates of national fertilizer supply and consumption, as well as information available through the LUD regarding licenses issued to fertilizer importers and retailers, the Myanmar fertilizer market is growing rapidly. It is estimated that farmers used 1.5-1.6 million t of inorganic fertilizers (product tons) in 2016. In 2014, IFDC estimated fertilizer use totaled about 1.2 million t. Thus, during the past two years, it appears that, in aggregate, Myanmar farmers have increased fertilizer use by 20-30%. That level of growth is consistent with estimates (10-15% per annum) provided by major fertilizer companies in Myanmar.

Due to the absence of national statistics on fertilizer use, Gregory et al. (2014) estimated fertilizer use by product based on extensive discussions with major importers/fertilizer processors and various government officials. The estimated use of fertilizers by individual products, total products, and total nutrients for 2013/14 is shown in Table 8 (column 2).[34] The 2013/14 estimates of fertilizer product use were extrapolated to 2016/17 based on the estimated total fertilizer use of 1.5 million t (Table 8, column 3).

The factors that underpin the growth in farmer demand may be linked to GOM policy reforms (which opened international and domestic trade opportunities in agriculture, including fertilizer) and the private sector's favorable response to the business opportunities afforded. The private sector has: (1) improved farmers' physical access to fertilizers (e.g., with fertilizer imports and extension of dealer networks); (2) improved knowledge of crop- and zone-specific fertilizer requirements (e.g., based upon companies' own research trials); and (3) introduced new fertilizer-related technologies with good potential to benefit farmers

[33] Assumed fertilizer consumption is calculated based on estimates of fertilizer imports and domestic manufacture of urea fertilizers. There are no fertilizer exports from Myanmar.
[34] Gregory et al. (2014) estimated that Myanmar farmers applied 1.2-1.4 million t of fertilizers in 2014.

(e.g., bulk blending, soil testing, fertilizer products that contain secondary and micronutrients, and electronics-based advisory services for farmers).

Table 8. Estimated Fertilizer Use in Myanmar, 2013/14 and 2016/17

Column 1 Fertilizer Product	Column 2 Fertilizer Use 2013/14 (t)	Column 3 Fertilizer Use 2016/17 (t)
Domestic urea	200,000	150,000
Imported urea	500,000	770,000
Ammonium sulfate	1,750	2,300
Calcium ammonium nitrate	740	1,000
NPK compounds	300,000	390,000
Diammonium phosphate	7,000	9,000
Triple superphosphate	90,000	118,000
Muriate of potash	20,000	26,000
Other	21,500	33,700
Total Product	1,140,990	1,500,000
Estimated nutrient value		
Nitrogen (N)	371,070	484,100
Phosphate (P_2O_5)	91,345	117,000
Potash (K_2O)	57,150	74,100

Despite the recent growth in the fertilizer market, there is significant potential for further gains. In view of nutrient removal through agriculture and compared to global fertilizer use, the intensity of fertilizer use in Myanmar remains very low. According to World Bank Indicators (2017),[35] world fertilizer consumption is 140 kg of nutrients ha^{-1} compared to only 21 kg nutrients ha^{-1} in Myanmar. Based on Figure 2, it is estimated that farmers are using about 52 kg of nutrients ha^{-1}; that is less than 37% of the world average. In rice production, it is estimated that a 3 t ha^{-1} yield removes about 125 kg of nutrients. Thus, Myanmar farmers are replacing only about 52 kg through the addition of inorganic fertilizers, the main nutrient supply source. In addition to the low use levels, fertilizer application (while apparently improving) is unbalanced. Due to the dominant role of urea (46% N) in farmer fertilizer use practices, the NPK use ratio is unbalanced in favor of nitrogen. The NPK ratio is estimated to be 6.5:1.6:1. Improved knowledge of crop- and zone-specific fertilizer recommendations is necessary to provide the "knowledge foundation" for improvement. And technology transfer to farmers is fundamental to farmer

[35] World Bank. 2017. *World Development Indicators Online (WDI) database*. https://data.worldbank.org/indicator /AG.CON.FERT.ZS

adoption and best use practices for fertilizers. Balanced fertilizer use is a requisite of improved yields (quality and quantity) and sustainable agriculture production systems.

5.2 Structure of the Fertilizer Market in Myanmar

The Myanmar fertilizer market is open and freely competitive. As reflected in the factors that underpin the growth in fertilizer demand (Section 5.1 – Fertilizer Demand), both the public and the private sector have a role to play in the Myanmar fertilizer market.

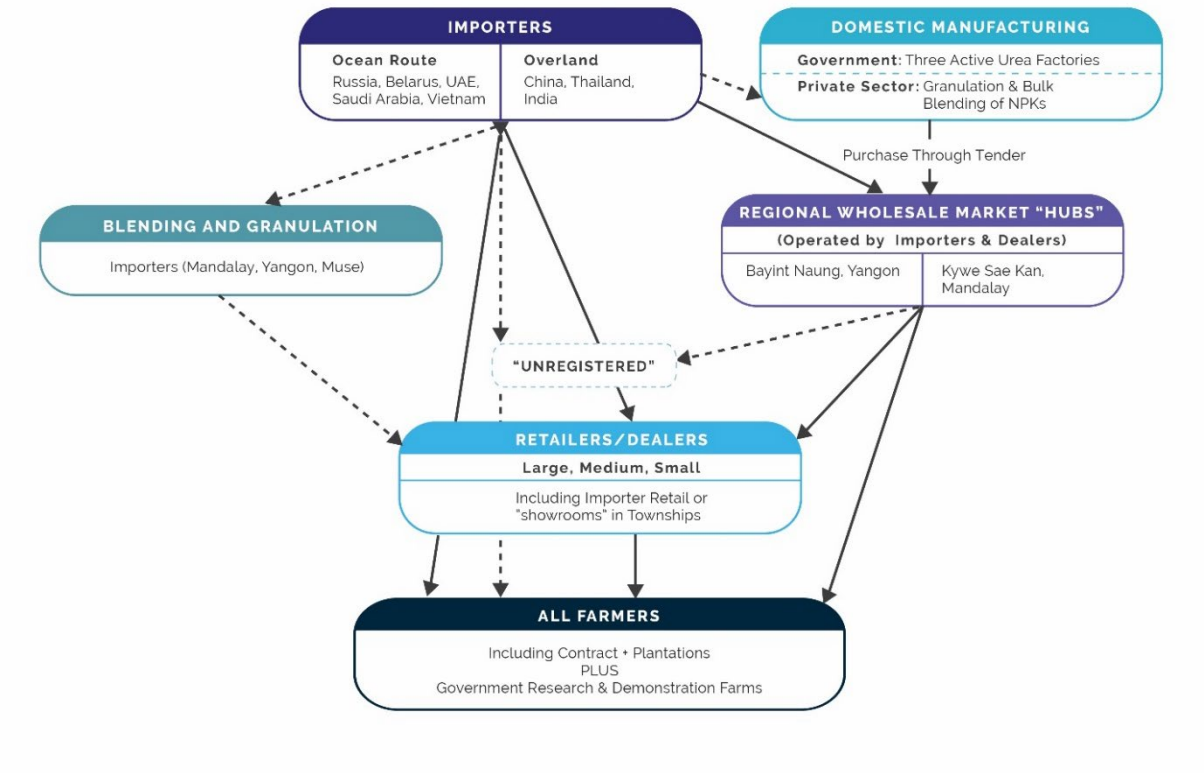
5.2.1 The Fertilizer Value Chain

The fertilizer value chain (Figure 1) in Myanmar is evolving in compliance with the Fertilizer Law. As indicated in Table 7, the government's role, through the MOALI, is in administration of the regulatory and licensing provisions of the Law and, through the Ministry of Electricity and Energy, the manufacture and sale of domestically produced urea fertilizers. The MOALI, through the DOA, is also engaged in farmer education and technology transfer; however, funding limitations constrain field activities. The MOALI Myanmar Agriculture Development Bank (MADB) and Myanmar Livestock and Fisheries Development Bank (MLFDB) provide annual production loans to enable farmers to purchase production inputs. The MADB provides crop loans to farmers. However, the loan provisions are usually limited to rice production, in value per acre and total number of acres (e.g., 10 acres maximum). Repayment terms limit farmer flexibility on timing of crop sales, essentially meaning that farmers must sell marketable surplus at harvest rather than storing their harvest for sales at better prices.

Essentially all commercial activities related to fertilizer supply and marketing are handled by the private sector, which is also engaged in brand-specific farmer education and technology transfer.

As illustrated in Figure 1, the value chain is rather straightforward, with importers negotiating with international and regional suppliers for fertilizers to meet their needs. China is the major supplier of fertilizers to Myanmar, with sales at international market prices. Thailand is also a significant supplier. Collectively, China and Thailand account for about 80-90% of the fertilizers entering the Myanmar market. The main entry point to Myanmar is Muse (Northern Shan State) for overland imports from China. The main entry point for fertilizers imported from Thailand is Myawady (Kayin State). In addition to overland shipments, about

100,000-200,000 t of fertilizers are imported annually via the port of Yangon, mainly from Russia and United Arab Emirates.



Source: IFDC field survey (2017) and various reports.

Figure 1. Fertilizer Value Chain in Myanmar

Each year, the GOM-owned/operated urea fertilizer factories supply an estimated 150,000-200,000 t of urea. The urea that is manufactured domestically is directed at meeting the government's requirements, with the majority being sold to Myanmar private fertilizer companies through open auction. Auction sales are in 5,000 t lots.

- **Fertilizer Importers and Wholesalers**

The private sector is responsible for all fertilizer imports in Myanmar. Imports are at prevailing world market prices. Once the imports arrive, either overland or by sea, there are two major warehousing/wholesaling points in the country. The two major fertilizer wholesale "hubs" are located in Yangon and Mandalay and are comprised of wholesalers and distributors, most of whom are importers storing their products for distribution to various destinations. Yangon and Mandalay provide strategic locations for distribution to productive areas in the south and central/north part of the country. At the Yangon wholesale market,

products from China (coming overland through Muse in the northeast) can be found, which are then distributed to retailers (large, medium, and small) in the Delta region and neighboring areas, while in Mandalay, one can find products that were shipped through the port of Yangon or through the border with Thailand.

Official fertilizer imports during fiscal years (FY) 2015 and 2017 totaled an estimated 1.6 million t and 1.4 million t, respectively (Table 9). In FY 2017, the value of fertilizer imports was U.S. $302.8 million. Informal cross-border trade is common but not considered significant in terms of total imports. For example, based on the estimates of fertilizer use in Table 8, in 2016/17 1.5 million t was used, of which 1.4 million t was imported and most of the remainder was likely locally produced urea.

Table 6 lists the types of chemical fertilizers that are imported. Organic fertilizers are also imported. Some are International Organization for Standardization (ISO) certified. For example, "Vedagro" is an ISO-certified organic fertilizer in the market with minimum 45% OM, 10% N, 4.5% K_2O, 0.3% P_2O_5, and "many kinds of micronutrients and amino acids." The qualitative description in labeling further highlights the lack of research in product registration procedures and the potential for contamination of soils with heavy metals and other harmful chemicals.

The number of licensed fertilizer importers/wholesalers has increased from 242 in 2010 to 628 in 2015. In 2014, Gregory et al. estimated that 80 of the registered importers were "serious" fertilizer suppliers, with annual turnover ranging from 10,000 to 400,000 t. This estimate coincides with the information provided by the Myanmar Fertilizer, Seed and Pesticide Entrepreneurs Association. Association membership (which totaled 70 in 2017) accounts for about 80% of Myanmar's fertilizer imports.

Table 9. Fertilizer Imports ('000 t)

Year	Overseas	Border Trade	Total
2005/06	172	313	485
2006/07	75	234	309
2007/08	37	393	430
2008/09	18	235	253
2009/10	22	627	649
2010/11	61	740	801
2011/12	134	684	818
2012/13	166	971	1,137
2013/14	309	1,025	1,334
2014/15	268	928	1,196
2015/16	446	1,131	1,577
2016/17			1,400

Source: Department of Trade.

- **Fertilizer Manufacturers and Processors**

Domestic fertilizer production is limited to basic fertilizer manufacture by the government and local value-added processing by private sector firms. Basic fertilizer manufacture is limited to ammonia/urea production. Under the purview of the Ministry of Electricity and Energy, the government owns five ammonia/urea factories (Table 10). The total nameplate capacity is 603,000 t of urea, based on the capacity of all five factories.[36] However, the nameplate capacity of the three factories now in operation is 360,000 t of urea (Table 11). Due to various factors, including technical issues, ongoing interruptions, and capacity utilization efficiency in the supply of natural gas, the primary feedstock for nitrogen production, ammonia/urea capacity utilization efficiency is very low at 40-58% for the operating factories; this is extremely low by world standards. With urea production estimated at about 150,000 t in 2016, domestically sourced urea accounts for about 10-15% of total farmer urea use.

[36] Urea (46% nitrogen content) is the world-leading solid nitrogen fertilizer product. It is available in either prilled or granular form, depending upon the production process. The urea manufactured in Myanmar is in the prilled form. In general, urea in the granular form trades internationally at a slight premium compared with prilled urea. Granular urea offers physical properties that are superior to prilled urea in the bulk blending of fertilizers.

Table 10. Ammonia/Urea Fertilizer Factories in Myanmar

Unit #	Location	Year Commissioned	Capacity (t per day)	Status
1	Sale-A	1970	200	Operating
2	Kyun Chaung	1971	210	Closed
3	Kyaw Zwa	1985	600	Closed
4	Myaung Daga	2010	500	Operating
5	Kan Gyi Daunt	2010	500	Operating

Table 11. Urea Fertilizer Production in Myanmar ('000 t)

Year	Production[a]	Production[b]	Nameplate Capacity[c]	Capacity Utilization
2006/07	105		303	34%
2007/08	98		303	32%
2008/09	106	106	303	34%
2009/10	72	70	303	24%
2010/11	184	35	360	10-51%
2011/12	180	166	360	46-50%
2012/13	160	209	360[d]	44-58%
2013/14		156	360	43%
2014/15		166	360	46%
2015/16		130	360	36%
2016/17	150 (est)	82	360	42%

a. Source: Land Use Division, Yangon Region, May 2014.
b. Source: Myanmar Petrochemical Enterprise.
c. Annual nameplate capacity for urea manufacture for three operating factories, based on daily capacities and 300 operating days per year.
d. Two older units closed.

The private sector is engaged in value-added processing. The processing involves primarily bulk blending (physical mixture) of imported commodity-type fertilizers (e.g., urea, ammonium phosphate, and MOP) to achieve a desired fertilizer grade. Bulk blending fertilizer technology allows tailoring of fertilizer grades to specific soil and crop requirements. Bulk blended products are an alternative to granulated NP or NPK products that are manufactured in granulation factories. Both technologies are accepted worldwide in the supply of high-quality multi-nutrient fertilizers. In some cases, the Myanmar processed "blends," as well as imported granulated NPK fertilizers, contain secondary and micronutrients. In addition to the processors that are engaged in steam granulation and fertilizer blending, one company has recently started grinding basic slag to achieve a product that will provide nutrient value and soil amendment, targeting acidic soils. The domestic processing capacity and annual output are not known.

There are locally produced organic fertilizers in Myanmar made from raw materials such as weeds, swamp and river grasses, straw, rice husks, bean waste, etc. These have a low nutrient content of 1.2:1.5:0.5 plus 2.2% Ca, 0.5% Mg, 0.4% S, and 23.5% organic matter (OM); 1:3.5:12 plus 4.0% Ca, 0.3% Mg, 0.5% S, and 21.5% OM; and 8.7:3.3:5.2 plus 2.5% Ca, 0.4% Mg, and 38.3% OM. The latter has been enhanced with natural potassium nitrate (ex Chile) and phosphate rock (ex Egypt). Basic slag or calcium silicate fertilizer (30% CaO, 15% SiO_2, 3% MnO, and 1.5% P_2O_5) is also marketed as an organic or natural fertilizer with a recommended application rate of 2-16 bags/acre or 200-2,000 kilograms per hectare (kg ha^{-1}).

- **Fertilizer Retailers**

The number of licensed fertilizer retailers (dealers) has increased dramatically from 1,600 (2010) to 3,200 (2014) and then to 5,200 (2017). In addition to licensed fertilizer retailers, some leading private sector fertilizer companies have estimated that there may be up to 20,000 retail fertilizer sales points, comprised of sub-dealers and general merchandise traders engaged in very small volume sales. Sub-dealers and traders with annual fertilizer sales below 5 t per year are not required to be licensed as a fertilizer retailer. The network of licensed dealers extends throughout the country; on average, each dealer serves about 1,300 farmers.

Recent surveys by IFDC in Ayeyarwady indicate a strong connection between retailers and wholesalers. Retailers make telephone calls for supplies from the Yangon wholesale market after receiving inquiries from farmers for various products and quantities. These orders from farmers help retailers to gauge how much to procure from wholesalers for their area of operation. In addition, some importers/wholesalers have financing arrangements with retailers to store their products, supplying them with products to push into these markets while providing an incentive. These incentives include credit to be repaid in cash or in kind (paddy) with an interest rate of 2% or more per month.

- **Myanmar Fertilizer, Seed and Pesticide Entrepreneurs Association**

The Myanmar Fertilizer, Seed and Pesticide Entrepreneurs Association was established in 2013. Its primary purposes are to (1) support improved agriculture sector performance through the proper use of improved production technologies and (2) represent the common

interests of the private sector in the orderly development and functioning of the markets for fertilizers and seeds. Initially with a membership of the 20 largest private sector seed and fertilizer companies in Myanmar, association membership in 2017 totaled 70 companies, representing 80% of the imports of fertilizers.

6. The Fertilizer Law and Regulatory System

6.1 The Fertilizer Law

The Fertilizer Law enacted in 2002 established the basic legal and regulatory provisions and guidelines that govern the fertilizer market in Myanmar. In 2015, the Fertilizer Law was amended to modernize it. Under the purview of the MOALI, the Law provides a market-oriented policy environment. The Law is administered through the Fertilizer Committee, chaired by the Deputy Minister of MOALI, with the Director General (DG) of DOA serving as its Secretary and the Director of the Land Use Division serving as Co-Secretary. Other members are DGs from the Department of Planning, Directorate of Trade, Department of Cooperatives, Department of Customs, and Department of Energy, as well as the Commander of Police Force and President of the Union of Myanmar Federation of Chambers of Commerce and Industry.

Functioning under the authority of the Fertilizer Committee, the Fertilizer Technical Committee (FTC) serves to provide the technical expertise on fertilizer-related matters. The FTC is comprised of eight members, with five representatives of the DOA (including the DG as Chairperson and Director of LUD as Secretary), two representatives of the DAR (DG serving as Deputy Chair), and one representative of YAU. The FTC examines all registration applications prior to their approval or rejection by the Fertilizer Committee. The license applications for storing or distributing and selling fertilizers in Myanmar are examined, and licenses are granted or rejected by the DOA. The renewal of registration certificates and licenses follows the same process.

The Fertilizer Law and its 2015 Amendment address the key elements typical of fertilizer legislation and regulations in a market-oriented fertilizer industry. It provides a set of guidelines that are applicable to fertilizer trade and quality control in Myanmar, mainly registration of fertilizer products; registration of businesses for importing, manufacturing, or exporting fertilizer; and licensing of businesses for storage or distribution and sale of

fertilizer. However, important elements of the Fertilizer Law and its 2015 Amendment are inadequately covered; for example: (1) fertilizer-related terms and definitions are incomplete and (in some cases) lack clarity and/or conformity with internationally accepted definitions; (2) labeling requirements are not adequately provided; (3) tolerance for allowable variations in nutrient content and bag weight, minimum percentages of nutrient content claimable, and maximum allowable heavy metal limits are not stipulated; and (4) violations and associated penalties are not well-defined.

Regulations normally include a provision for all businesses to be registered with the designated authority. Registration constitutes a legal bond under Myanmar Law between the authority and the seller of fertilizers, which ensures that the latter is aware of the regulations, understands their meaning, and agrees to abide by them. It also provides a mechanism to identify all sellers of fertilizers in the country so that the authority and the inspection team know who they are regulating. In addition, it allows the inspection team to randomly and fairly select sellers for inspection. Although these processes look transparent in Myanmar, they do not appear to be regular and automatic. Particularly, the current system allows non-registered sellers to avoid inspection, since they are not included in the LUD/DOA database of dealers. The database should be better organized and complete to include all key information on every registered business.

6.2 The Fertilizer Regulatory System

The MOALI LUD is the government agency responsible for fertilizer product registration, fertilizer inspections, and laboratory analyses of collected samples. The LUD Director serves as Co-Secretary of the Fertilizer Committee and Secretary of the FTC.

As indicated earlier, the LUD has two fertilizer analytical laboratories. The main LUD laboratory in Yangon is fully equipped to conduct complete analyses of fertilizers and is responsible for testing all fertilizers for registration purposes. The LUD laboratory in Mandalay was established in 2013/14 and is equipped to conduct analyses of major and secondary nutrients only. In total, LUD conducted 1,257 and 2,606 chemical analyses of fertilizer samples in 2014 and 2015, respectively.

The LUD protocols and methodologies for fertilizer inspection, including sampling and analyses, generally follow the guidelines of the Fertilizer Control Order of India (1985). The

India Control Order is generally compliant with internationally accepted standards. However, it includes language specific to the India fertilizer policy framework, which does not apply to Myanmar.

The LUD has adapted the India Control Order inspection protocols to its requirements and capacity limitations. LUD basically relies on product testing at registration as the quality control "checkpoint" and only sporadically draws samples at various points in the supply chain. LUD also conducts a fertilizer analysis if a farmer files a complaint regarding fertilizer quality. The overall effect of the LUD inspection protocol is *an over-reliance on the testing of products at registration as the "quality assurance check," with little attention to post-registration fertilizer quality checks in the market.*

7. Soil Degradation in Myanmar – Contributing Factors and Implications for Agriculture Production Systems

During the past four years, each of the Myanmar national strategic action plans and strategy-related documents identifies soil degradation as a key concern that must be properly addressed to support agricultural transformation. Soil degradation is defined as a change in the soil health status, resulting in a diminished capacity of the ecosystem to provide goods and services for its beneficiaries. It is, therefore, one of the major threats to future life. Soil degradation comprises physical, chemical, and biological processes. Rainfall, surface runoff, floods, wind erosion, tillage, mass movements, soil compaction/deformation, and prevented carbon sequestration are examples of physical processes that lead to the loss of fertile soils and declining soil quality and functionality. The reduction of soil nutrients due to nutrient mining, alkalinity, and acidity, loss of organic matter, or waterlogging can be regarded as a chemical component of soil degradation. The loss of biodiversity due to non-site-adjusted soil management results in both a change in microbial activity, which affects crop yield, and sustainability of soil productivity. Soil productivity relates to the chemical, physical, and biological properties of the soil and its ability to sustain crop production. Soil productivity can be improved, but also degraded, through agricultural practices. Conservation tillage (or no-till cultivation) is an example in which soil productivity can be improved. Farmers, with the help of researchers and extension services, must conduct localized field trials to evaluate what works best in their area and for their particular cropping system.

About 43% of the total area of Myanmar is forested. However, deforestation and forest degradation have occurred at an alarming rate due to past practices of wide-scale timber harvesting as well as shifting cultivation, expansion of agricultural lands, urbanization, infrastructure development, fuel wood deficit, and conversion of forest lands to other land use. Excessive removal of vegetative cover, practice of the slash-and-burn system with its shortened fallow period, and overgrazing are major factors causing watershed degradation. The effect of these practices is most detrimental in the Central Dry Zone, where prolonged exposure of land with limited and poor vegetation exacerbates soil erosion and nutrient losses. Poorly maintained irrigation facilities, including dams and canals, and inefficient management of water from dams to farms not only hinder crop production, but also lead to soil degradation due to poor land cover. In recent years, restoration of degraded forests, conservation of mangroves, and greening of dry zones and hilly areas have been implemented.

Low nutrient application in Myanmar, especially the low level of inorganic fertilizer use, is defined in Section 5.1 – Fertilizer Demand. Lwin et al. (2014)[37] suggest that this is a major contributing factor to declining agricultural productivity. Low nutrient application not only results in low production, but also leads to rapid depletion of soil nutrients (see box).

Soil Nutrient Depletion

To illustrate the nutrient removal challenge that confronts Myanmar agriculture, a 5-t ha^{-1} rice yield removes at least 73 kg N ha^{-1} with all crop residue recycled. Most farmers in Myanmar apply only a single bag of urea fertilizer per acre (i.e., a high analysis fertilizer containing 23 kg of nitrogen per 50-kg bag). Even with a 40% recovery of the nitrogen in surface-applied urea (i.e., N recovery by the crop of less than 10 kg of applied N, a very high estimate), the balance of 63 kg N ha^{-1} will be supplied by soil. Such soil N supply is possible with a soil organic matter content of 3% or higher. However, based on Myanmar soils and current farmer practices, soil organic matter content is less than 3% and the N balance is negative (mining of N from soil).

Note: The general recommendation for Myanmar farmers planting hybrid rice is to apply two-and-a-half 50-kg bags of compound fertilizer per acre and 25 kg/acre of urea (MOALI, 2012).

[37] Lwin H.Y, T. Myint, S. Than, N.M. Aung, C.C. San, and T. Htut. 2014. *Role of Fertilizer Policy in Transforming Agriculture of Myanmar*, ReSAKSS Asia, Facilitated by International Food Policy Research Institute (IFPRI), Washington, D.C.

By comparing Table 4 and Table 8, it is evident that in 2016/17 about 800,000 t of N was removed through crop harvesting and about 500,000 t N was applied as fertilizer. Based on an N recovery rate from surface-applied urea (25-40%), the net N nutrient shortfall in 2016/17 was ~600,000-675,000 t. Under optimum conditions, the soil does not have the scope for that level of N supply potential. The only presently available option to maintain soil nutrients at a level to support the intensive, high-yield agriculture possible with high-yielding variety (HYV) seed and good water management is application of high nutrient-containing fertilizers at the recommended rates. However, integrated application of manure, compost, and crop residue as nutrient sources can reduce the amount of fertilizer applied. The integrated approach also improves the use efficiency of applied fertilizers and soil health because organic inputs provide carbon, the energy source for soil microorganisms for more efficient nutrient cycling. As illustrated in Figure 2, the current rate of fertilizer and manure application in Myanmar must increase to increase agricultural productivity without degrading soil resources.

In addition to high yield potential, soils with high nutrient values contribute to other important components of human health (namely, nutritional needs, such as vitamins, proteins, carbohydrates, and oils). As production of staples increases, the extra yield is most often due to added carbohydrates and leads to dilution of the micronutrient content. Many of the healthful components of food are boosted by the application of mineral nutrients. Micronutrients important to human nutrition can be optimized in the diet by applying them in balanced fertilizers to crops.

	Fertilizer	Manure	Deposition	Fixation	Sediments	Production	Residue	Leaching	Gaseous	Erosion
K2O	5	1	8		4	-24.1	-62.4	-2	0	-10
P2O5	7.8	2.5	3		2	-17.5	-4.1	0	0	-6
N	39	2	8	25	0	-53.1	-22.2	-5	-8	-15

Note: Based on Table 4.

Figure 2. Calculated Nutrient Balance for Myanmar

In Europe, North America, and many parts of Asia, the agricultural practice of depleting plant nutrient reserves (nutrient mining) for farming ceased several decades ago. Unfortunately, nutrient mining continues in Myanmar (Figure 2). The low use (or absent use) of fertilizers and other nutrient sources not only makes the agriculture system more vulnerable to climate variability, it exacerbates climate change. These factors are interconnected and major contributors to the cycle of poverty. Declining soil fertility and lower biomass production result in reduced amounts of crop residue, root biomass, and soil organic matter, leading to poor soil structure, reduced groundcover, and increased runoff, erosion, and leaching losses. Overall, such soils are characterized by reduced buffering for water, nutrient, and organic matter retention and increased soil acidification, greenhouse gas (GHG) emissions, and vulnerability to climate stress.

8. Fertilizer's Impact on the Environment and Its Mitigation Role

Fertilizers are needed to overcome nutrient and yield gaps caused by soil mining and, on a sustainable basis, to balance the difference between nutrients required for optimal production and those provided by soil and other nutrient sources – organic resources, recycled wastes, etc. However, misuse of fertilizer can lead to adverse environmental impacts (see box). The concerns of soil nutrient mining are addressed in Section 7.

Negative Consequences of Misuse of Fertilizers

- Overuse and poor application practices contribute to eutrophication, GHG emissions, nitrate leaching, soil acidification, and (in some cases with poor quality fertilizer products) heavy metal contamination.
- Underuse contributes to soil nutrient mining, low crop yield quality and quantity, and other factors that contribute to land degradation.

The United States Environmental Protection Agency[38] reports that agriculture accounts for 24% of global greenhouse gas emissions (2010); that is second to emissions from global electricity and heat production at 25%. Mineral fertilizers account for 33% of total annual creation of reactive N. Runoff and leaching (in sandy soils) of phosphatic fertilizers are also responsible for eutrophication of lakes and rivers. In general, 45% of P in water bodies is associated with agriculture. The major cause of eutrophication is associated with misuse of P fertilizers (overuse on sandy soils and mining of soil P – underuse), farming on steep land, poor erosion control, and lack of conservation agriculture.

Most fertilizer in Myanmar is surface-applied (i.e., broadcast). There are some exceptions in upland crops, where fertilizer is placed in a furrow. But in the case of urea, which accounts for about 60% of the fertilizer used in Myanmar (Table 8), almost all is surface-applied. Once applied in agriculture, N is highly mobile, with crop recovery below 50% of the applied N. The major pathways for N loss, expressed as a percentage of N applied, are: NH_3 volatilization (10-65%), NO_3^- leaching and runoff (1-20%), and nitrification-denitrification (1-30%). Management, topography, soil type, or weather drive the N loss mechanism that

[38] https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Sector.

predominates in a given location and season. Crops grown in soils with a high level of organic matter typically have the best N recovery ratios.

The role fertilizer plays in economic viability, environmental sustainability, and food safety and nutrition is most evident in the floating farms of Inle Lake in Southern Shan State, where all factors must be in balance to support agriculture, tourism, and biodiversity.

8.1 Mitigating the Impacts

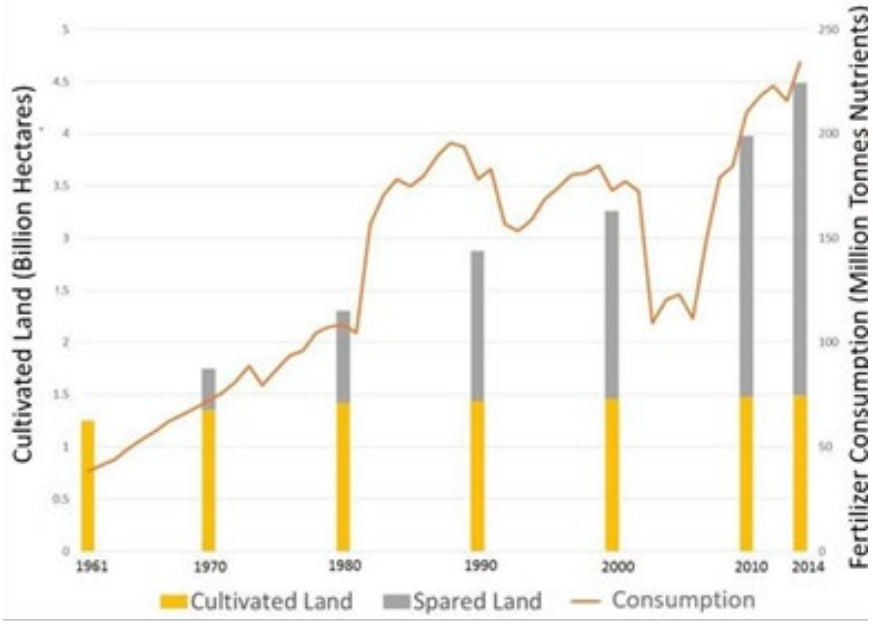
Good agricultural practices (GAPs) improve fertilizer use efficiency, increase farmer profitability, ensure environmental sustainability, improve food safety and quality, and make farming socially acceptable. An innovative approach to effectively address the economic, social, and environmental effects and consequences of fertilizer use is the 4R Nutrient Stewardship platform.[39] Adopted by the global fertilizer industry, the 4R Nutrient Stewardship platform embraces the concept of the 4 "**R**ights" – apply the **right source of nutrient**, at the **right rate**, at the **right time**, and at the **right place**. A simple concept, the 4R initiative is knowledge-intensive and site-specific; it is highly appropriate for Myanmar agriculture.

An effective method to reduce N losses and improve fertilizer use efficiency is urea deep placement (UDP) technology. UDP is effective in increasing nutrient uptake by crops and reducing losses to N loss pathways when complemented as component of GAPs. Gaihre et al. (2016)[40] reported UDP increased yield on average by 21% compared to broadcast urea while using 25% less fertilizer. UDP reduced ammonium and ammonia volatilization to a level similar to the control treatment; losses of N were significantly higher with broadcast urea. UDP reduced N_2O emissions by up to 80% as compared to surfaced-applied urea under flooded conditions. The effect of UDP on N_2O emissions under the alternate wetting and drying (AWD) irrigation practice depended on the duration and intensity of soil drying, with emissions reduced under mild drying, but emission of N_2O increased with more intense drying. These results confirm that UDP not only increases N use efficiency and grain yields,

[39] International Plant Nutrition Institute. 2013. *A Pocket Guide to 4R Nutrient Stewardship.*
[40] Gaihre, Y.K., U. Singh, A. Huda, S.M.M. Islam, M.R. Islam, J.C. Biswas, and J. DeWald. 2016. "Nitrogen Use Efficiency, Crop Productivity and Environmental Impacts of Urea Deep Placement in Lowland Rice Fields," *Proceedings of the 2016 International Nitrogen Initiative Conference Solutions to Improve Nitrogen Use Efficiency for the World*.

but also saves on costs and reduces negative environmental impacts, including N_2O emissions.

On a global scale, intensive crop production with improved fertilizer use has increased food production with a minimal increase in cultivated land (from 1.2 to 1.5 billion ha) during the past 65 years (Figure 3). For every hectare spared from slash-and-burn agriculture, about 20 t CO_2-equivalent emissions are prevented.[41] Fertilizer use increases carbon sequestration through higher crop and biomass yields that result in absorption of more CO_2, some of which is held in the soil organic matter. In Myanmar, very low levels of carbon are sequestered in the soil due to very low levels of fertilizer use and associated soil degradation. Proper use of fertilizer has good potential to enhance sequestration of additional C in soils, thus contributing to fertilizers' impact on climate change mitigation.[42]



Note: Based on FAO (2017) and World Bank (2017) data.

Figure 3. Relationship Between Fertilizer Consumption, Cultivated Land, and Land Spared

In addition, there is a wide range of "enhanced efficiency fertilizers" on the market to increase nutrient uptake by better timing of nutrient release. Some enhanced efficiency N

[41] Angle, J.S., U. Singh, C.O. Dimkpa, P.S. Bindraban, and D.T. Hellums. 2017. "Role of Fertilisers for Climate-Resilient Agriculture," Proceeding 802, International Fertilizer Society, London, U.K.
[42] Sombroek, W.G. 1994. *Aspects of Soil Organic Matter and Nutrient Cycling in Relation to Climate Change and Agricultural Sustainability*, International Atomic Energy Association (IAEA) and FAO, Vienna, Austria.

fertilizers use urease inhibitors, nitrification inhibitors (e.g., neem), and/or slow- or control-release coatings such polymers, sulfur, or gypsum. Ultimately, the improved products and practices should result in better synchronization of N release with crop N demand. Since the N uptake pattern also differs by crop and agro-ecologies, the selection of products and management should be site-specific.[43]

There are 17 essential nutrients (including C, H, and O) required for healthy crop growth. Application of nutrients such as P, amendments like lime for subsoil acidity, and mycorrhizae that improve root development and K in osmotic regulation can increase the resilience of crops to drought stress. Micronutrients, notably Zn, Cu, and B, mitigate drought effects in plants by several mechanisms, including increasing water use efficiency, maintaining membrane stability which otherwise causes tissue flaccidity by drought-induced wilting, and detoxifying toxic free radicals that accumulate in plants during water scarcity. These micronutrients are components of several enzymes and control plant processes related to abiotic stresses, water, or nutrient uptake.

8.2 Importance of Integrated Soil Fertility Management

Plant nutrients from both organic and inorganic sources are needed for higher crop production. Inorganic fertilizer plays a critical role in the world's food security, but the highest yields are often the result of using organic and inorganic sources together. ISFM practices include the use of fertilizer, organic inputs, and improved germplasm, combined with the knowledge of how to adapt these practices to local conditions, aiming to optimize agronomic use efficiency of the applied nutrients and improve crop productivity. All inputs need to be managed following sound agronomic and economic principles. ISFM combines all the agronomic components necessary to make crops grow and yield well, including the use of high-yielding and healthy planting material, plant nutrients (whether supplied as organic materials or mineral fertilizers), and other soil amendments. Therefore, ISFM is not characterized by unique farm practice, but its approach is to combine available technologies in a manner that preserves soil health while promoting its productivity and profitability.

[43] Agyin-Birikorang, S.J., J. Fugice, U. Singh, J. Sanabria, and S, Choudhuri. 2017. "Nitrogen Uptake Kinetics for Key Staple Cereal Crops in Different Agro-ecological Regions of the World," *Journal of Plant Nutrition*, 40 (7):995-1023.

The ISFM approach embraces the principles of plant production ecology, where yield is a function of the interaction between genotype, environment, and management (i.e., optimizing fertilizer and organic resources, along with improved genetics, weed and insect control, and use of modern technology). The approach is critical to optimizing food production and efficient use of plant nutrients. The approach also helps ensure that improving Myanmar's soil fertility status is embedded within the ISFM paradigm and will be achieved in large part through the increase in agronomic efficiency as fertilizer use grows with time. In ISFM, the need for "local adaptation" takes into account the variability between the inherent soil fertility and the amount of production resources. ISFM emphasizes the importance of using often scarce resources like fertilizer and organic inputs efficiently while reaching economic goals that are achievable for each farm household. The resources available to the farmer, government policies, and market conditions are also a part of the decision process in full ISFM implementation. The goal of ISFM is to maximize the interactions that result from the potent combination of fertilizers, organic inputs, improved germplasm, and farmer knowledge.

The ISFM concept uses fertilizer as the main entry point for nutrient management but integrates the use of organic sources, capturing the benefits of increased soil organic matter, which include improved efficiency in nutrient benefits associated with inorganic fertilizer. For example, the synergism between mineral and organic fertilizers is utilized to increase the bioavailability of nutrients from organic fertilizers when mineral fertilizer application promotes microbial activity, root growth, and increased rhizosphere activity. Organic fertilizers improve water and nutrient retention capacity of the soil, resulting in increased fertilizer use efficiency. This results in improvement of agronomic efficiency in nutrient use and productivity of all types of soils. The ultimate outcome is improved productivity, enhanced soil quality, and a more sustainable system through wiser farm investments and field practices with consequent minimal impacts of increased input use on landscape and ecological resources. The 4Rs principles of inorganic fertilizer use are adapted to ISFM – using the right source, at the right rate, at the right time and in the right place – contribute to improved productivity, profitability, and environmental stewardship. Research, extension and technology transfer of best ISFM practices is critical to stabilizing and sustainably improving the quality of Myanmar soils and facilitating agriculture transformation to achieve improved returns to farmers and long-term agribusiness growth.

9. Key Challenges and Opportunities

Improved soil fertility management in Myanmar depends on various factors, including: (1) increased farmer knowledge and adoption of improved soil management practices, such as ISFM in general and application of the 4Rs concept in the case of inorganic and organic fertilizer use; (2) an efficient and effective fertilizer sector that provides farmers timely access to high-quality and appropriate fertilizer products; and (3) reliable crop markets where market and price risks are manageable. During the past decade, progress in the systems that impact improved soil fertility management has been varied. Deficiencies in many of the systems that underpin the fertilizer sector persist (e.g., knowledge development and technology transfer to farmers, financial services, quality assurance, complementary agriculture production systems, crop markets). The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis presented in Table 12 is useful in guiding strategic interventions to improve soil fertility in Myanmar.

Table 12. Strengths, Weaknesses, Opportunities, Threats (SWOT) Analysis

STRENGTHS	WEAKNESSES
a. Government of Myanmar (GOM) priority on: improving agriculture sector performance, accelerating farmer adoption of modern technologies, establishing sustainable agriculture production systems. b. Attention to elements of ISFM being emphasized by public, private, and NGO stakeholders c. GOM policy based upon fertilizer market-economy facilitating an active, dynamic private sector engaged in fertilizer supply, knowledge development/transfer, and improving farmer access to fertilizers. d. Private sector committed to long-term fertilizer market development. e. Farmers eager to adopt improved agricultural technologies if convinced of quality and potential returns. f. Crop diversification is expanding with improved returns to farmers, highlighting need for best management practices for fertilizers. g. Fertilizer market increasing rapidly with emphasis on balanced fertilizer use. h. Favorable fertilizer supply systems based upon low-cost imports – excellent proximity to major international suppliers. i. Financial service system providers progressing with services to fertilizer value chain members/farmers. j. Priority attention to development of complementary seed sector and water management systems. k. Development of agribusiness/trade opportunities contributing to crop market improvements. l. Major neighboring markets for agricultural produce.	a. Public sector soil and fertilizer research activities do not adequately address site-specific nutrient management. b. Linkages between public sector research and extension underdeveloped, resulting in poor soil and fertilizer information dissemination. c. Farmer knowledge of ISFM and 4Rs concept low. d. Fertilizer dealer advisory capacity on fertilizer is low. e. Inconsistency in messaging systems from various stakeholders, including NGOs, on soil fertility management. f. Financial service systems underdeveloped in servicing needs of farmers and fertilizer dealers. g. Poor availability of fertilizer market information to support decision-making: time-series data on key fertilizer-market related issues (supply, demand, price) unavailable. h. Fertilizer Law inadequate in clarity and completeness. i. Deficiencies in public and private sector systems to mitigate product quality risks contribute to uncertainty and low confidence in fertilizer quality at all levels – public sector, private sector, farmers. j. Farmers confused by many fertilizer products in the market. They get information from friends, family, trial and error. k. Domestic ammonia/urea factories are uneconomic due to technical issues and natural gas feedstock supply interruptions.
OPPORTUNITIES	**THREATS**
a. Strengthened public-private sector linkages in research and technology transfer to improve farmer knowledge on ISFM and elements of 4Rs concept. b. Dealer role strengthened to support technology transfer to farmers. c. Financial service providers extend facilities to improve farmer loan provisions of MADB and dealer access to finance. d. Fertilizer Law reform to achieve an international standard of completeness and clarity. e. Linkages with regional and international agriculture research centers to upgrade research programs on soil-fertilizer-crop research. f. Public and private sector linkages with NGOs. g. Strengthened public and private sector risk mitigation systems for fertilizer quality.	a. Continued weakness in farmer knowledge of soils management required for IFSM and 4Rs concept. b. Continued violation of fertilizer "truth-in-labeling" and associated low confidence in quality. c. GOM fertilizer and soil research fails to establish needs-driven research in soils and fertilizers to better target ISFM systems and fertilizer products to zone-specific soils and crops. d. Ineffective research and extension linkages and associated weakness in information dissemination to farmers and input dealers. e. Weak crop markets with associated weakness in farmer access and price uncertainty. f. Financial service providers targeting farmers and fertilizer value chain members unsuccessful in meeting credit needs. g. Fertilizer market information limited and constrains decision-making. h. Little or no improvement in research facility and skills and training of research and extension personnel.

10. Scope of Soil Fertility and Fertilizer Management Strategy

10.1 Rationale for Soil Fertility and Fertilizer Management Strategy – Why Is It Important?

The preceding text has made the case for a Soil Fertility and Fertilizer Management Strategy (SFFMS).

- Soil fertility and fertilizer cannot be separated. Sustainable soil fertility improvement depends on best fertilizer management practices and high-quality products.
- Soil and its fertility are finite resources and underpin food and human nutrition.
- Current agricultural production systems in Myanmar are mining the soil of nutrients, placing the country on a dangerous spiral into land degradation.
- Replacing nutrients removed by crop harvests requires an integrated approach that is site-specific to account for:
  - Inherent soil fertility.
  - Availability of local fertilizer products and amendments (crop residues, organic wastes, lime, dolomite, gypsum, phosphate rock).
  - Farming systems (crop rotations, livestock integration).
  - Water resources.
  - Availability (and cost) of commercial fertilizer products (organic and inorganic).
- A strategy to support agricultural productivity without depleting natural resources is critical to the long-term prosperity of the nation.

Limiting and reversing soil degradation in Myanmar are significant challenges.[44] The challenge for a Soil Fertility and Fertilizer Management Strategy is to combine the important value of organic materials and biological agricultural products in improving soil quality and improving nutrient uptake efficiency, with appropriate application and farmers' improved knowledge and use of inorganic fertilizer products. The scope of the SFFMS specifically targets:

[44] Sustainably improving the productive capacity of Myanmar's soils is a key objective of the MOALI. Achievement of that objective will require the application of all available tools and resources that limit and reverse soil degradation, including improved water management, and reduction/minimization of activities and farmer practices that contribute to soil erosion. In addition to efficient use of inorganic fertilizers, it will also require application of available organic soil improvement materials and use of biological materials that may contribute to nutrient uptake and yield improvement.

- Improving systems that impact ISFM knowledge development and technology transfer to improve farmer adoption of best use practices in soil management.
- Strengthening the legal and regulatory framework that impacts supply and commercial activities of inorganic fertilizers, organic products, and biological products intended to benefit plant growth and development.
- Improving farmers' access to and use of fertilizer products most appropriate to their specific crops and soils based upon agronomic and economic considerations.

10.2 Vision

The ADS draft (GOM, 2016a) establishes the strategy and investment plan that will guide agricultural transformation in Myanmar – from a society based upon agriculture to one that derives most of its income from services and industry. The *vision* for Myanmar agriculture is a "*highly productive agriculture sector that contributes to a food-secure nation, increased farmer incomes to lift the rural population out of poverty, and international trade competitiveness of Myanmar agriculture products*." Achieving the vision will require ongoing attention to soil and fertilizer-related issues that can contribute to the sustainability of agriculture. Complementary to the vision for Myanmar agriculture is the **vision of the soil fertility and fertilizer management strategy**. It is: *Myanmar farmers properly applying ISFM concepts in agriculture production systems with a market-driven fertilizer sector working with the public sector to provide high-quality products accessible and affordable to farmers, to build and maintain soil fertility that will underpin a highly productive and mechanized agriculture sector.*

Achieving the *vision* entails the following:

- Extension services (public and private) engage with Myanmar farmers in an integrated soil fertility management approach – utilizing farm mechanization, organic materials, and biological products with the appropriate use of inorganic fertilizers.
- Fertilizer research programs are strengthened to focus on current soil fertility and fertilizer-related issues. National agricultural research services collaborate actively with regional and international agricultural research centers (IARCS), NGOs, and universities on soil/soil fertility-related issues.
- Private sector fertilizer companies in Myanmar supply high-quality fertilizers in a timely manner, through extended networks of trained fertilizer dealers, affording farmers ease of access to fertilizer products and advisory services on products best-suited to their needs.

- Quality of fertilizer products sold by, and the proper recommendations provided with those to farmers, are assured through strengthened public and private sector systems and increased collaboration. Timely and accurate fertilizer market information is readily available to all stakeholders.
- Timely and accurate fertilizer market information is readily available to all stakeholders.
- Public and private sector stakeholders are cognizant of environmental impacts of fertilizer use, including contribution of fertilizers to climate change and climate change mitigation.

To support the vision will require:

- Strengthened and re-oriented public sector soils and soil fertility research programs that (i) further knowledge of ISFM best management practices, including updated fertilizer recommendations (by specific crop and agro-ecological zone) and (ii) effectively disseminate updated research findings and related information to public and private sector stakeholders.
- Strengthened and fully engaged technology transfer agents (public and private sectors as well as NGOs) to improve knowledge of best management practices for the elements of ISFM.
- Upgraded Fertilizer Law and associated implementing regulations that provide for completeness and clarity on all fertilizer-related[45] technical and trade issues.
- Strengthened fertilizer quality assurance programs through improved effectiveness of field inspections and oversight (based on "truth-in-labeling" concept, upgraded laboratory capacity and functioning of the LUD, and strengthened private sector quality-risk mitigation systems).
- Strengthened financial service systems that adequately meet the financial needs of fertilizer value chain members and farmers.

The fertilizer sector in Myanmar is advancing rapidly in terms of increased farmer use of fertilizers, private sector expansion in imports to achieve adequate supplies, and extension of dealer networks to afford farmer access. Achievement of the above *vision* will build on the solid foundation already established, paving the way for further gains to support agricultural transformation.

[45] Among other issues, the Fertilizer Law will need to address all fertilizer-related products that are either imported or locally manufactured/processed for commercial sale, including inorganic, organic, and biological products.

10.3 Values

Two "values" emerged from stakeholder consultations and a workshop held in October 2017. It was noteworthy that stakeholders emphasized (a) the role of organic matter and organic fertilizer in soil fertility management and (b) the importance to allay the perception that fertilizers are "bad" and that the domestic industry is corrupt.

Based upon these discussions, the "values" may be expressed as follows:

- **To manage the soils of Myanmar so they continue to provide the productivity necessary for food security and income generation.**
  - Farmers have the knowledge required to apply an integrated soil fertility management system.
  - A reorientation of research so that it is needs-driven to recommend soil fertility management practices that are both profitable and sustainable.

- **To enable a socially responsible private sector to provide high-quality fertilizer products of the right type at the right time in the right place.**
  - Improved functioning of a public and private partnership-type environment that is compliant with the Fertilizer Law.
  - A self-regulating private sector that places high-quality fertilizer products on the market.
  - Fertilizer market information, costs, and benefits to be freely available to farmers.

- **To provide Myanmar farmers with the best technology that will allow them to improve their livelihoods in the face of climate change.**
  - A research and extension program that addresses resilient cropping systems and cultural practices that will mitigate impacts from extreme weather events.
  - Knowledge-based systems available through public services, private service providers, and electronic applications (online and via smartphone apps) are needs-driven and have a consistent message.

10.4 Targets

The preceding text has established that farmers in Myanmar use little fertilizer in unbalanced applications, which leads to soil mining of most essential nutrients. The targets for this strategy need to correct this. Just as the Myanmar Rice Sector Development Strategy targets

16.13 million t of milled rice production by 2030 by maintaining 7.7 million ha of rice area with an average yield of 4.2 t ha^{-1} per cropping season, then the Soil Fertility and Fertilizer Management Strategy must sustain this production, without diminishing, but building, soil fertility. Therefore, the targets for the Soil Fertility and Fertilizer Management Strategy underpin a highly productive agriculture sector.

By 2030:

- 80% of the cultivated land in Myanmar will have site-specific fertilizer recommendations for all crops grown.
- 100% of farmers will have access to the knowledge required for integrated soil fertility management for their farm.
- 100% of farmers will have access to high-quality fertilizer products that are appropriate for ISFM.
- The Fertilizer Law will be revised to include: (i) clear fertilizer-related terms and definitions; (ii) provision for labeling requirements; (iii) tolerance for allowable variations in nutrient content and bag weight, minimum percentages of nutrient content claimable, and maximum allowable heavy metal limits; (iv) a fertilizer legal and regulatory framework to provide a mechanism that ensures consumer/farmer protection as well as protection for fertilizer businesses; (v) a requirement for providing data (regional fertilizer consumption patterns and company deficiency reports) that can be reported through a regulatory system; and (vi) well-defined violations and associated penalties.
- A regulatory system is functioning, through government quality control regime at all levels in the value chain and private sector self-regulation to ensure the Fertilizer Law is enforced. Low incidence of infringement.

10.5 Strategic Objectives

The Soil Fertility and Fertilizer Management Strategy includes four interrelated strategic objectives that will contribute to achievement of the vision and the associated targets mentioned above. They are:

Objective 1: Improve the fertility status of Myanmar soils to support sustainable improvement in agriculture productivity

Achievement influencing factors *– Strengthened public and private sector systems that impact fertilizer quality, soil fertility and fertilizer knowledge development, and technology transfer. Farmers apply integrated soil fertility management practices, including: (i) balanced fertilizer use (N:P:K ratio with requisite secondary and micronutrients) integrated with available organic sources and amendments and based upon crop- and zone-specific requirements; and (ii) sourcing and proper application of organic and inorganic inputs, as well as biological/natural products, that maximize nutrient uptake by the crop, improve water and nutrient retention in the soil, and minimize losses through runoff, leaching, and volatilization (primarily N fertilizers).*

Objective 2: Enhance efficiency in fertilizer value chain to improve farmers' access to and use of high-quality fertilizer products

Achievement influencing factors *– Reform of Fertilizer Law to achieve an international standard. Private sector investment in fertilizer value chain results in high-quality fertilizer products that are available in a timely manner and affordable to farmers through expanded dealer networks; strengthened implementation of public and private sector systems to mitigate fertilizer quality risks; market transparency improved to support strategic decisions; effectiveness of technology transfer systems (public and private sector) fortified; and financial services systems extended to/within the value chain to farmers. While private sector companies promote their own brands, common messaging (by all actors) to farmers on soil fertility management technologies are site-specific and consistent with integrated soil fertility management.*

Objective 3: Increase farmers' economic returns from fertilizer use

Achievement influencing factors *– Widespread farmer adoption of integrated soil fertility management technologies and best management practices in fertilizer use management. Continuation of market-oriented fertilizer supply system and value chain with high competition in rural markets. Improved farmer access to (and participation in) markets at harvest with improved crop price and market assurance/stability. The provision of sound financial services to farmers offering better alternatives and more choices and competition to avoid the "loan trap" with unfavorable conditions that are currently prevalent in parts of Myanmar's rural communities.*

Objective 4: Reduce adverse impacts of fertilizer on the natural environment, ecological resources, and climate change

Achievement influencing factors *– Farmers improve soil fertility management, with emphasis on application of ISFM technologies and 4Rs of fertilizer use, based upon updated fertilizer recommendations and soil tests. Strengthened monitoring systems in place to measure impacts of fertilizer manufacture and use on the natural environment.*

10.6 Key Themes and Interventions

The key thematic areas will support achievement of the vision of the Soil Fertility and Fertilizer Management Strategy for Myanmar. The interventions that flow from them will directly contribute to achievement of the strategy objectives identified above.

The relationship between the strategy objectives and thematic areas is illustrated in Table 13.

Table 13. Linkages between Strategy Objectives and Thematic Focal Areas of the Myanmar Soil Fertility and Fertilizer Management Strategy

Theme/Objective	Objective 1	Objective 2	Objective 3	Objective 4
	Improve soil fertility to support sustainable improvement in agriculture productivity	Enhance efficiency of fertilizer value chain to improve farmer access to and use of high-quality products	Increase farmers' returns to fertilizer use	Mitigate adverse impacts of fertilizer on climate and ecological resources
Ensure sustainable soil fertility improvement	X		X	X
Ensure farmer access to information on soil fertility management	X		X	X
Emphasize the role of fertilizer use management in climate-smart agriculture	X	X	X	X
Update and fortify the Fertilizer Law and associated implementing regulations	X	X	X	X
Ensure sustainable supply of high-quality fertilizers with improved farmer access	X	X	X	
Ensure high-quality fertilizers are consistently available in the market	X	X	X	X
Monitoring and strategic planning	X	X	X	X
Strengthen financial services		X	X	
Institutional and human capacity building are needed at all levels in the fertilizer sector	X	X	X	X
Strengthen post-harvest markets and improve farmer access to markets	X	X	X	

10.6.1 Research

Prioritizing soil fertility and fertilizer research on a targeted, needs-driven basis will underpin soil fertility improvement. Improvements in soil fertility management and fertilizer use originate from research that is designed to deliver: (a) more in-depth understanding of Myanmar soils, including soil characteristics and soil nutrient status; (b) crop- and agro-ecological zone-specific nutrient requirements (macro, secondary, and micro level); (c) the best management practices and benefits of ISFM technologies under various cropping systems in conjunction with use of associated agricultural technologies – farm mechanization, HYV seeds, crop protection products, crop residue management, and irrigation systems;

(d) identification of the available organic and natural mineral products and their potential impacts in soil improvement; (e) the role and application of biological materials that impact nutrient uptake by various crops; and (f) the ecological and climate change impacts of fertilizer-related technologies under alternate use scenarios. The public and private sectors, as well as international organizations and NGOs, have important roles to play in generating research findings that will impact soil fertility and fertilizer strategies for Myanmar. The thematic areas below target research-related interventions.

10.6.1.1 Theme 1. Ensure sustainable soil fertility improvement

✓ *Modernize national soils maps*

During the past half-century, Myanmar soils have changed due to the effects of land degradation, including deforestation and associated soil erosion, nutrient mining, and the increased occurrence of problem soils (often associated with global climate change). The most recent national soils maps are seriously dated (1970s). The LUD is in the process of updating the maps; this will lead to improvement in understanding the status of Myanmar's agricultural soils and improve decision-making regarding land use. Accelerating the application of GIS technologies will lead to improvements in precision mapping and in the timely availability of the maps. The design and methodology used to generate the updated and improved soil map of Myanmar should be such that it provides the shortest and most effective route to improving Myanmar's crop fertilizer recommendations. Since the ultimate objective is crop- and agro-ecological zone-specific fertilizer/nutrient recommendations, soil maps are a means to reaching this end. A national workshop to update stakeholders on the status of Myanmar soils and the changes that are occurring is fundamental to improved soil fertility management.

✓ *Develop fertilizer recommendations that are tailored to specific crops and agro-ecological zones*

There are no current official crop-specific fertilizer recommendations for the various zones in Myanmar, seriously compromising the application of ISFM. Despite the tremendous agro-ecological (soil and climate) diversity in Myanmar, only one single fertilizer recommendation per crop exists at the national level, i.e., a "blanket fertilizer recommendation." There are more than 3,000 registered fertilizer products, comprising 40-50 different formulations (nutrient grades or ratios) in Myanmar. The product mix is determined by the private sector importers/local processors based upon their own

business plans. In some cases, the product grades are determined by the individual companies based on fertilizer field trials and crop response factors. In others, it is unclear if the grades being sold are the most appropriate (nutrient values, cost per unit of nutrient, agronomic performance factors) for the farmers.

Establishing closer linkages between seed research programs and soil research will facilitate better identification of crop nutrient requirements of specific varieties and ISFM practices that will deliver optimum results. This intervention will result in crop- and zone-specific fertilizer recommendations. Field trials are needed to validate the fertilizer recommendations that have resulted from the mapping of Myanmar's soils, to test and improve these and yield evidence-based crop- and agro-ecological zone-specific fertilizer/nutrient recommendations via spatially defined fertilizer/nutrient recommendation domains. A slate of modern fertilizer products that are most appropriate to the specific crops/zones will allow farmers to select the most economical and appropriate products. Increased farmer adoption of ISFM technology will improve soils and increase resource use efficiency. It will fortify the capacity of Myanmar soils to maintain and supply essential crop nutrients.

✓ *Accelerate provision of soil and plant testing services with an emphasis on improving farmers' use of soil and plant testing*

> ***Soil testing*** *is critical to improved efficiency in fertilizer use – providing information on the nutrient values present in specific soils and indicating other soil characteristics that impact soil nutrient uptake and limit crop growth. It is a key diagnostic tool that will help to prevent fertilizer overuse and underuse.*

Soil testing to identify soil characteristics and soil nutrient status in specific farmer fields is not widely done in Myanmar. Therefore, farmers that use fertilizers often select the products based upon either past experiences or recommendations of neighbor farmers and fertilizer dealers. In some cases, farmers select the lowest cost fertilizer product, irrespective of cost per unit of nutrient and the product quality. Such practices may result in either over- or under-fertilization and/or application of inappropriate products with negative impacts on farmer returns and the environment. Some large fertilizer companies in Myanmar provide limited soil and plant test services to farmers in their target markets,

particularly for high-value crops. The private sector does not have the capacity to provide such services on a widespread basis.

This intervention targets strengthening the performance of LUD in providing soil testing services to farmers until affordable, reliable, and user-friendly field diagnostic technologies are available. As use of this important diagnostic tool expands, farmers will derive benefits in understanding more site-specific nutrient requirements – specific nutrient needs and the amount of each nutrient required as well as other soil improvement opportunities (e.g., addition of liming materials and organic matter). A particular point of attention is to advance and enhance the soil analysis system toward increasing its capacity to process high volumes of soil samples. Furthering the benefits of LUD soil tests, in combination with the spatially defined crop- and agro-ecological zone-specific fertilizer/nutrient recommendation domains generated by the updated soil map of Myanmar and its field test validations, the fertilizer industry will be positioned to better tailor the slate of fertilizer products (products that may contain secondary and micronutrients) to specific crops and soils. Achieving a proper use level of fertilizers containing specific nutrient values is consistent with ISFM technology and environmental stewardship.

Opportunities also exist to learn from experiences of Thai farmers on the use of simple soil test kits for recommendations associated with soil pH, N, P, and K in rice and maize.[46]

- ✓ *Improve fertilizer use efficiency*

  Inorganic fertilizers are needed to supply the requisite high nutrient levels needed to achieve agriculture transformation in Myanmar. High analysis (solid) fertilizers, such as commodity-type fertilizers (urea, DAP, TSP, MOP, and some NPK grades), provide an excellent foundation for the fertilizer product mix in Myanmar. Currently available technologies allow for augmentation of commodity-type fertilizers to include secondary/micronutrients. Such technologies are appropriate to Myanmar and flow from the increased knowledge of crop-specific fertilizer requirements.

[46] Wongmaneeroj, Audthasit. 2017. "From Site-Specific Nutrient Management or Tailor-Made Fertilizer to Soil Clinic in Thailand," Proceedings of the Myanmar Soil Fertility and Fertilizer Management Conference, 18-19 October, 2017, Nay Pyi Taw, Myanmar.

In addition to improving product selection, this intervention aims to improve the efficiency of crop recovery of nutrients applied and available in the soil. Application of inorganic fertilizers alone is not sufficient to achieve sustainable agriculture systems. Improved use of appropriate organic materials will enhance efficiency in crop uptake of applied nutrients. Expanded understanding of technologies, such as urea deep placement technology and products that control the release of nutrients, will allow for improved knowledge transfer to farmers.

- ✓ *Strengthen research programs with emphasis on ISFM technologies*
  ISFM practices embrace the principles that underpin sustainable agriculture production systems; they will directly contribute to higher crop yields. Adapting MOALI LUD, DAR, and YAU research programs to target ISFM will contribute to further knowledge-building on best management practices – taking inventory of available on-farm resources and waste products that have soil improvement properties, identification of best handling and management to achieve high-quality organic products, accumulation and storage options, and approaches to integration in soils along with inorganic fertilizers.

  ISFM will contribute to soil quality improvements and improved use of available soil improvement materials, particularly on-farm materials that are easily available with no/little "out-of-pocket" cost. Reform of the Fertilizer Law to include language pertaining to commercial activities involving organic soil improvement materials will play an important role in ensuring farmers have access to high-quality and properly identified/labeled products.

- ✓ *Strengthen further knowledge of the potential impacts of biological materials in yield improvement*
  Biological materials have potential to improve nutrient supply to crops. The appropriateness and effectiveness of such products are influenced by many factors. Expansion of the MOALI LUD and DAR research programs to include the evaluation of products that may be appropriate to Myanmar agriculture and the identification of best use and management opportunities will support farmer decision-making on which materials may benefit them and how best to achieve good results. The reform of the Fertilizer Law with language specific to commercial activities (import/local

manufacture/processing and sale) of biological materials for crop growth will further protect farmer interests.

- ✓ *Expand and intensify stakeholder collaboration/information-sharing on soil fertility and fertilizer research*

  This intervention targets increased sharing of information of fertilizer-related research and development findings and results, thereby ensuring research results impact technologies and soil fertility practices at the farm level. Research collaboration (i.e., involving various MOALI departments and divisions, the university system, and relevant government ministries) will pay early and enduring dividends through: (a) strengthened public sector research priorities on soils and fertilizer-related issues and (b) advancing the introduction of technologies that will impact farmer returns and yield improvement.

  The Myanmar Fertilizer, Seed and Pesticide Entrepreneurs Association may be an appropriate body to link with a collaborative workshop to share information of fertilizer research priorities and results. Sharing of research results with international agriculture research organizations, university system programs, development assistance organizations/projects, and NGOs engaged in agriculture/agribusiness development will strengthen Myanmar research systems. Greater collaboration will support delivery of improved fertilizer-related knowledge and consistency in messaging to farmers on best fertilizer use management.

10.6.2 Agriculture Extension and Technology Transfer

Fortified and more active agriculture extension and technology transfer systems will foster farmer uptake of new technologies. Strengthened linkages between research and development programs and agriculture extension services will enhance farmer adoption of ISFM and associated best use practices.

Myanmar farmers have demonstrated their willingness to invest in new technologies that will improve yields. The fertilizer market in particular is growing rapidly, as reflected in: (a) annual increase in fertilizer demand of about 10-15% over the past five to seven years to a total of about 1.5 million t of fertilizers used in 2016; (b) the introduction of fertilizer formulations tailored to specific crops and soils; and (c) the entry and/or expanded presence

of fertilizer-related technologies, including: (i) biological materials, (ii) organic fertilizer products, and (iii) fertilizer materials based upon waste products.

While the recent growth in the fertilizer market is impressive, most farmers do not have adequate knowledge of:

- The specific fertilizer products (from the wide array of fertilizer grades) best suited to their crops and soils.
- The role of various crop nutrients in crop health.
- Nutrient deficiency symptoms in crops at various growth stages.
- Cost per unit of nutrient contained in various fertilizer products, thereby enabling the purchase of inputs that provide the best value based upon nutrient value and field performance.

Technology transfer to farmers will close the knowledge gap. The public and private sectors as well as international agriculture development organizations and NGOs have key roles to play in improving technology transfer systems.

10.6.2.1 Theme 2. Ensure farmer access to information on soil fertility management

✓ *Strengthen the public sector's role in technology transfer to farmers throughout Myanmar*

Improving farmer access to sound information on soil nutrient management and the roles and benefits of inorganic and organic fertilizer products as well as biological products will improve on-farm productivity and returns from agriculture.

Agriculture activities (crop, livestock, post-harvest) yield organic materials that have value in the supply of nutrients either directly to the soil or in fortifying the soil's capacity to improve efficiency in crop uptake of applied inorganic fertilizers. In many cases, farmers are using on-farm organic materials that improve their production systems.

This intervention is to strengthen the public sector systems that provide knowledge transfer to farmers. Strengthened and more active agriculture extension services (provided through the LUD, with interactive linkages with Myanmar research organizations) with emphasis on a greater field presence (targeting farmer education through farm-level trainings and fertilizer technology field days) are a priority. Improved use of technical

leaflets on fertilizer-related technologies, signboards in rural areas, and multimedia will further improve technology transfer to farmers. Synergies in farmer education accrue from active participation of private sector input dealers in public sector extension programs and vice versa through public-private partnership. To increase the reach of information and recommendations to farmers, modern dissemination techniques (online and smartphone apps), in addition to traditional ones, should be used. Facebook and smartphone apps are popular among farmers. Online portals and smartphone apps also can be shared with and incorporated into the advisory services provided by private sector players, NGOs, and others active in this field to ensure greater reach of proper fertilizer and soil fertility recommendations to farmers and a common message relayed to farmers from various players.

- ✓ *Encourage private sector companies to promote technology introduction and knowledge transfer to input dealers and farmers with "common" messaging*

  The private sector agriculture input suppliers in Myanmar are active in promoting their own brands. In some cases, that includes products that have enhanced values of secondary and or micronutrients and other value-added properties. Based upon field tests involving their products, they provide training to fertilizer dealers on the benefits derived from their products. The dealers then advise farmers on fertilizer product selection.

  Agro-input dealers, as the last link in the fertilizer value chain and with direct contact with farmers, are well-positioned to provide farmers with good advice on which fertilizer products provide the best value (in terms of field performance) and on best management practices (e.g., 4R concept). Improving dealer knowledge of fertilizers and crop-soil-water interactions will enhance their capacity to provide advisory services to farmers. It will also complement efforts to provide much-needed "common" messaging to farmers. As dealers are often trained in the agriculture university system, they generally are knowledgeable about crop production and should quickly grasp fertilizer-related knowledge. Moreover, based upon their presence in the local community with ongoing contact with their farmer customers, they are well-positioned to have a good relationship with farmers based upon integrity and trust.

- ✓ *Encourage non-governmental organizations to provide farmers, either directly or indirectly through input supplier training, knowledge on soil fertility and fertilizers*

  NGOs are uniquely positioned to transfer knowledge to farmers on soil fertility and fertilizer management. Often serving farmers in targeted rural areas with high incidence of poverty and food insecurity, they can be an excellent source for advisory services on crop production systems well-adapted to the localized environment. The advice provided is typically not linked to brand-specific products but rather based upon sound technical practices involving locally available on-farm materials (e.g., organic materials from livestock, poultry, and cropping activities) as well as inorganic fertilizers. Many employ ISFM technologies in their farmer education programs, which involve classroom-type sessions and on-farm demonstrations). Better linking the agriculture-oriented NGOs to public and private sector technology transfer agents will promote "common" messaging regarding soil fertility and fertilizers, including the application of ISFM technologies.

- ✓ *Strengthen linkages between agriculture research and extension to further knowledge transfer to farmers*

  As indicated above, technology transfer is an ongoing process, influenced by research findings and technology advances that originate within and outside of Myanmar. Effectively transferring technology to farmers relies upon backward and forward information flows to bridge the information gap; in Myanmar, the linkages between research (mainly public sector) and the extension staff are weak. The fact that most extension staff are graduates of the agriculture university system is important for a science-based understanding of soils, soil fertility, and fertilizers and crop-soil-fertilizer interactions. Strengthening research and extension linkages through workshops, conferences, and jointly conducted field events will improve backward and forward information flows. Ultimately, the improved linkages allow for the more timely and ongoing flow of information to farmers on soil fertility issues and improved fertilizer technologies. Making online tools and smartphone apps available to extension agents and training agents and using them properly to advise farmers can contribute to enhanced knowledge transfer.

10.6.3 Reduce the Negative Impacts of Fertilizer Use on Climate Change, the Natural Landscape, and Ecological Resources

It is well-established that fertilizers (their use and non-use) have consequences that impact the natural environment and contribute to climate change. In Myanmar, fertilizer use is very

low by global and regional standards, with the intensity of fertilizer use (calculated as applied nutrients per hectare of arable land) estimated to be less than one-third of global fertilizer use. While the potential for adverse fertilizer impacts will increase with growth in the market, at current low use levels, the negative impacts of fertilizer are more related to land degradation associated with soil nutrient mining and reduced biomass production. In addition, there are some reported instances of fertilizer runoff due to either localized "over-application" and/or poor application practices. There is also some uncertainty regarding fertilizer quality in Myanmar, which may impact farmers' use of products that contain hazardous elements.[47] Finally, fertilizer manufacturing and processing activities are occurring in Myanmar; both have potential environmental impacts. Improved awareness of the potential adverse impacts of fertilizer manufacture and use in specific locations and their causal factors is a first and key step to understanding the magnitude of the environmental impacts and identifying proactive measures to bring about needed changes.

10.6.3.1 Theme 3. Emphasize the role of fertilizer use management in climate-smart agriculture

✓ *Adopt improved soil management practices – integrated soil fertility management systems with best management practices for inorganic fertilizers and utilization of organic materials to maximum extent*

This intervention emphasizes the application of integrated soil fertility management technology, which encompasses maximizing the use of available on-farm organic materials that improve the nutrient retention and supply capacity of soils with nutrient enhancements derived from inorganic fertilizers. Due to their much higher nutrient supply potential, inorganic fertilizers (often high analysis/nutrient-containing products) are the starting point for ISFM technologies. Farmers in Myanmar are typically resource-poor, and MADB annual production loans do not cover the costs for efficient fertilizer use. Maximizing application of on-farm materials as well as affordable commercially available organic materials will be of benefit.

[47] Fertilizer materials (*both inorganic and organic materials*) may contain hazardous elements (typically of greatest concern are lead and cadmium, which may be present at varied levels in some fertilizers) that impact soil quality and may enter the food chain through crop uptake. It is not presently known if any fertilizer products being used in Myanmar contain high values of hazardous elements.

- ✓ *Improve water management through irrigation system rehabilitation and upgrades and expanded use of appropriate technologies*

  Improved water management will contribute to efficiency in fertilizer use, facilitating crop uptake of applied nutrients and reducing runoff. Improved water management will also reduce greenhouse gas release from applied nutrients. Irrigation systems are largely based upon use of surface water channeled to farmers' fields. Following years of poor maintenance, the systems are deteriorated. A review of the irrigation systems in each region with input from village-level farmers will provide useful insight on prioritizing investment in rehabilitation schemes. Increased on-farm use of technologies such as alternate wetting and drying may also contribute to improvements in water use efficiency.

- ✓ *Conserve natural resources, which are fundamental to sustainable agricultural production systems – sustaining soil productivity, limiting unnecessary deforestation, and limiting unnecessary crop production on marginal lands*

  Globally, agriculture is a major contributor to GHG emissions. One of the primary means of reducing GHGs from agriculture is by stopping the expansion of agricultural land, particularly marginal lands, and deforestation. It is well-established that more land has been spared from agriculture by the use of fertilizers (i.e., to improve soil fertility and support improved yields attained through introduction of new varieties) than any other technology. The Soil Fertility and Fertilizer Management Strategy for Myanmar is key to preserving the country's 43% of forest land area.

- ✓ *Reduce nutrient losses – proper application of fertilizers, conservation tillage where appropriate*

  The primary fertilizer nutrient loss mechanisms are through volatilization, denitrification, and leaching in the case of nitrogen and runoff and fixation in the case of other nutrients. An important step to mitigate nutrient losses is through farmer adoption of ISFM technology and the 4R concept in fertilizer use management. Balanced fertilization (hence the emphasis on soil- and crop-specific recommendations) is a key to maximizing crop nutrient uptake and will further contribute to a reduction in nutrient losses. On slopes and dry land with sparse vegetation, conservation tillage reduces losses of nutrients due to erosion, improves water infiltration, and reduces breakdown of soil organic matter (reducing GHG emissions).

Fertilizer product improvements and enhancements are available that will further reduce the adverse consequences of fertilizer use. Included are: (a) fertilizer deep placement (FDP), which reduces both runoff losses of N, P, and K and volatilization losses of ammonia, and (b) urea product enhancements that control nitrogen release and/or impact nitrification processes (e.g., urea coated with neem, gypsum, polymer, or sulfur, and/or with urease and nitrification inhibitors incorporated). Some of these products are becoming available to farmers in Myanmar. Improved understanding of their impacts on yield improvement and associated returns from their use and environmental impacts will impact their presence in Myanmar agriculture.

- ✓ *Mitigating impacts of domestic fertilizer manufacture and processing on the environment* Ammonia and urea manufacture is occurring in Myanmar with unquantified impacts on the environment. The manufacturing factories are old, based upon outdated technologies. Modern fertilizer plants are designed with better processing systems that minimize losses of gases that contribute to climate change. Plant design features also include processing systems and equipment for liquid and dust containment and waste recovery. Value-added fertilizer processing facilities include systems to mitigate material losses and ensure proper handling of waste. A complete assessment of the fertilizer manufacturing facilities in Myanmar will allow proactive measures to reduce the environmental impacts of fertilizer manufacture.

10.6.4 Strengthening the Fertilizer Law

10.6.4.1 Theme 4. Update and fortify the Fertilizer Law and associated implementing regulations

In October 2002, the GOM enacted the Fertilizer Law to provide the administrative and technical guidelines applicable to the fertilizer market. The respective roles of the public and private sectors are well-defined. Among others, the Law allows for a market-oriented fertilizer sector, with all commercial functions to be performed by the private sector. The government's role is limited to regulating the market. In 2015, the GOM enacted the Law Amending the Fertilizer Law to render the Law more complete in terms of regulatory provisions while retaining the market-oriented environment.

The GOM policy environment for fertilizers is conducive to private sector investment. The private sector has responded through investment in import and domestic marketing of

fertilizers valued at more than $300 million (2017 import value). Investments in domestic value-added processing are occurring at a rapid pace. Private sector-led efforts are extending to knowledge development on crop-specific fertilizer recommendations, technology transfer through dealer and farmer trainings, application of IT-based systems, use of technical leaflets, and farm-level demonstrations. A positive foundation is well-established for the fertilizer sector, based upon private sector-led growth.

- ✓ *Continue the market-oriented policy for fertilizer, relying on private sector investment in fertilizer supply and domestic marketing*

  A private sector-led fertilizer market offers advantages in cost and operational efficiency. The Fertilizer Law (enacted in 2002; revised in 2015) establishes a market-oriented fertilizer sector. Maintaining the market-oriented policy environment will foster further increases in private sector investment and contribute to associated market efficiencies in fertilizer pricing, product improvements, extension of dealer networks, and improved advisory services to farmers. Adjustments to the Fertilizer Law to improve completeness and clarity on issues that impact commerce in fertilizer-related materials, fertilizer quality, and consequences for violations will further strengthen the foundation for the fertilizer market.

- ✓ *Review and strengthen the Fertilizer Law and supporting legal instruments to achieve a modern international standard, comprehensive in scope and clear on all elements of the Law*

  The Fertilizer Law guides the public and private sectors in their respective roles in the fertilizer market. Numerous changes have occurred in global fertilizer markets, as well as in the Myanmar market, since the Law was enacted. Fortification of the regulatory guidelines contained in the Law to achieve a modern international standard of fertilizer-related terms and definitions (along with clarity and completeness) will contribute to improvements in fertilizer quality and (in particular) support the increased presence of high-quality organic fertilizers and biological crop growth materials. This can be achieved through new amendment of the existing law together with the development and adoption of implementing regulations. In addition, appropriate measures must be taken to ensure effective implementation and enforcement; these include adequate human, capital, and financial resources.

✓ *Require registration of all agro-input dealers and sub-dealers as well as general merchandise retailers that engage in fertilizer purchase for resale*

It is important that all businesses engaged in the sale of fertilizer materials maintain a proper license for fertilizer sales. At the sub-dealer and general merchandise trader levels, the Fertilizer Law exempts this requirement for low-volume dealers (e.g., less than 5 tons of sales per year). Revision of the Fertilizer Law to mandate licensing for all entities engaged in fertilizer commerce is important to fertilizer quality assurance. This licensing may be achieved through either (a) direct licensing of each sub-dealer/general merchandise trader or (b) indirect licensing, wherein the importer/wholesaler/retailer includes on their own license application the identification details of all low-volume sub-dealers/general merchandise traders it uses as channel members. Clauses on fair and market-conforming loan schemes must be included to professionalize the financial services system and prevent farmers from being trapped in a loan with poor conditions that do not reflect the market (also see Section 10.6.8.1).

✓ *Take all appropriate measures to effectively implement and enforce the Fertilizer Law together with adopted supporting regulations*

While the changes in the Fertilizer Law are needed, equally pressing is the need for implementation and enforcement of the Law with skilled staff and international standard fertilizer testing laboratories.

10.6.5 Fertilizer Supply and Market Development

Fertilizer supply in Myanmar is mainly based upon imports from international suppliers within the region. The government-owned and -operated urea factories supplement urea supply, accounting for about 15-20% of annual urea demand in 2017.

10.6.5.1 Theme 5. Ensure sustainable supply of high-quality fertilizers with improved farmer access

✓ *Fertilizer supply: continued supply through imports will contribute to supply system efficiencies*

The current strategy of relying on private sector imports to meet fertilizer requirements in Myanmar is favorable. Myanmar importers have well-established relationships with suppliers in key supply countries, namely China and Thailand, and have demonstrated expertise in negotiating competitive prices and timely delivery to Myanmar. Importers are

active in networking with international suppliers to maintain awareness of international market conditions that may impact import procurement.

For at least the medium term, global supply of nitrogen, phosphorus, and potassium fertilizers is expected to exceed demand by a comfortable margin, with associated weakness in international market prices. New investments in global fertilizer manufacture are occurring, mainly in areas endowed with low-cost fertilizer raw materials and in favorable proximity to major markets.

Of the three raw materials needed in basic fertilizer manufacture (potash, phosphate rock, and petroleum products), Myanmar possesses only economic quantities of natural gas, the primary feedstock in the production of ammonia and urea. Given production economic factors and the global fertilizer supply, demand outlook in Myanmar will benefit by continuing to rely on imports for fertilizer commodities, with local processing investments consistent with the business strategy of individual companies.[48]

✓ *Mid- to long-term (2022 and beyond) – Monitor global fertilizer market situation and evaluate economic options for fertilizer sector investment vis-à-vis competing opportunities for natural gas demand*

Under current conditions, Myanmar has no comparative advantage in domestic manufacture of basic fertilizers, given short- to medium-term global supply-demand factors and the proximity to world-leading fertilizer exporters and its known "economic" fertilizer raw materials reserves. However, it is important to be aware that the global fertilizer market is ever-changing. Albeit the global supply-demand situation is now contributing to a buyer's market[49] with low prices, history supports that such environments are subject to change, sometimes with relatively short notice owing to such events as political disruption, commodity crises, and food shortages. Maintaining an ongoing awareness of changing international fertilizer market conditions is important to future fertilizer supply planning, which may warrant indigenous production as more

[48] The local manufacture of urea is ongoing in three small-scale factories with poor economic return; subject to environmental impacts of the factories and priority needs for natural gas, urea supply from the factories may continue to supplement import supply in meeting local demand.

[49] The global fertilizer market is currently a "buyer's" market, defined as a market where ample global supplies are readily available for purchase and prices are low due to competition for sales. Myanmar importers typically practice "spot" buying, which yields favorable prices during a "buyer's" market situation. The private sector may benefit from longer term contractual relations with suppliers to ensure competitive prices in changing market conditions.

becomes known (in particular) about Myanmar reserves of natural gas (primary feedstock for ammonia/urea manufacture). In order to improve competition with imported urea and increase economic returns of locally manufactured urea, privatization of existing urea factories may be explored.

- ✓ *Continue private sector-based system with advances in value-added processing to better support balanced fertilizer use*

  The fertilizer market is evolving in a market-oriented manner. The private sector is investing its own funds in fertilizer supply and value chain development. Dealer networks are being extended to all major agriculture zones. The system that continues to emerge is cost-efficient and effective in providing farmers timely access to fertilizers.

  The private sector has led the way in the introduction of improved technologies, including bulk blending, soil testing services (limited scale), and IT-based farmer advisory services (limited scale), among others. Continued advances in technology introduction, including farm mechanization, will contribute to improved agriculture sector performance.

- ✓ *Farmer groups and private sector cooperatives to stimulate development*

  The formation of farmer groups is expanding among Myanmar farmers. The groups offer advantages to members in terms of accessing fertilizers and improving agriculture knowledge (e.g., information on improved seed technology, fertilizer use management, and plant protection). Farmer groups may also benefit from contracting arrangements to secure custom farm mechanization services – from land preparation to harvest. The formation of private sector farm cooperatives extend group formation to engagement in commercial activities that benefit members in supply of inputs and the sale of crops at harvest. Some cooperatives may also provide farmers improved access to financial services. Continued attention to development of the private sector cooperative system will support soil fertility management and fertilizer sector development.

10.6.6 Ensuring Farmers Have Access to High-Quality Fertilizers

Providing farmers access to high-quality fertilizer products appropriate to their needs is key to improved efficiency in farmer use and associated economic returns. However, fertilizer quality in Myanmar is uncertain. At all stakeholder levels, there is concern that the fertilizers being used are poor quality. Fertilizer quality pertains to chemical and physical properties of

the products and generally extends to include the weight of the content of the fertilizer bag and the presence of any foreign non-fertilizer materials. The "truth-in-labeling" concept applies in assessing quality. This means that the content of the fertilizer bag is consistent with the specifications on the bag label.

Both the public and private sectors have roles to play in ensuring that the fertilizers imported, manufactured, and processed are high quality and that high quality is maintained throughout the value chain to the point of final sale to farmers.

10.6.6.1 Theme 6. Ensure high-quality fertilizers are consistently available in the market

✓ *Strengthen Land Use Division's fertilizer inspection and laboratory analytical capacities, including protocols and methodologies*

The LUD plays a vital role in fertilizer quality assurance through inspection and sampling services and laboratory analyses of fertilizer samples.

Due to resource limitations, the LUD fertilizer inspection and regulatory operations currently in place are not optimal. Fertilizer inspections and collection of samples are primarily targeted at the import level, which is important to ensure that fertilizers imported to Myanmar are of an accepted standard. However, some fertilizers are entering Myanmar through "informal trade"[50] and thus not subject to LUD inspection requirements. Further, there is scope for fertilizer quality problems to occur at various points in the value chain – processor, wholesale/distributor, and dealer levels; inspections are not routinely done at "downstream" points in the value chain.

A re-orientation of the LUD approach to fertilizer inspections (namely, by extending LUD inspection services to the retail/dealer level) will increase efficiency in risk mitigation systems. Adaptation of internationally accepted sampling methods and procedures will improve LUD inspections. Both inspection protocols and product sampling methods and procedures may be published in the form of a standalone "Myanmar Fertilizer Inspection Manual." Full application of the "truth-in-labeling" concept, with attention to the legal requirements of bag markings, provides an important

[50] Myanmar has numerous border crossing points that provide opportunities for illegal border trade. Although thought to be limited in the total Myanmar fertilizer market context, illegal/informal imports of fertilizers to Myanmar are occurring.

element in the foundation for regulatory services (e.g., language used on bags, nutrient content of fertilizers, ceiling values for undesirable properties, bag weight).

LUD maintains one central fertilizer analytical laboratory in Yangon and a smaller laboratory in Mandalay. The laboratories are equipped for basic chemical analyses to assess nutrient values in fertilizers. However, they are not uniformly equipped to perform analyses for all micronutrients and the presence of heavy metals. Upgrading laboratory capacities (equipment and staff capacity) will further strengthen LUD in quality assurance.

The laboratory operations manual used by LUD to guide analytical methodologies is not specific to Myanmar.[51] Development and adoption of a national manual for fertilizer analytical procedures and methodologies, based upon internationally accepted methods, will strengthen fertilizer quality assurance.

Strengthening the Fertilizer Technical Committee to ensure that regulatory/advisory entities are established according to international standards for effective operations is also critical.

- ✓ *Improve private sector import procurement systems to mitigate quality risks*
  The private sector has established favorable relations with key import suppliers. To a large extent, import quality is based upon (a) factory visits to assess fertilizer processes and product quality at the manufacturer level and (b) importer-supplier trust. As part of the registration formalities, the importers also collect a sample of the fertilizers to be imported and submit the same to LUD for analyses and product approval/registration. While this approach appears to have been effective, the normal measures of mitigating product quality risk in international fertilizer procurement are much more stringent. For example, fertilizer quality assurance is based upon detailed contracted technical specifications supported by documentary evidence of quality (manufacturer's documentation) and validated through quality inspections at the point in the value chain where title passes from the supplier (i.e., exporter) to buyer (i.e., importer). Private sector

[51] The LUD uses the Fertilizer Control Order of India (1985) manual to guide its analytical procedures and methodologies in fertilizer analyses.

importer adoption of international standards in fertilizer import procurement will contribute to further risk mitigation in fertilizer quality.

10.6.7 Market Transparency

A provision of negative tolerance has been provided F.C.O. for the special situations. Though every manufacturer is required to manufacture the fertilizer only of standard prescribed, a limited relaxation (tolerance) are allowed. The tolerance limits prescribed for fertilizers are as follows:
1.(a) For Fertilizers with definite compound like Amm. Sulphate, Urea, Amm. Chloride, MOP, Superphosphate which contain more than 20% plant nutrients & also for $CuSO_4$, $ZnSO_4$, $MnSO_4$, $FeSO_4$.

Information on Myanmar fertilizer market conditions (international and domestic markets), including supply, demand, and prices, is critical to assessing farmers' use of fertilizers and factors that may impact use, including timely availability of supply and the profit incentive for farmers to apply fertilizer. At present, no public agency routinely collects data, performs data analyses, and disseminates fertilizer market information. Fertilizer market information is generally limited to: (a) data on imports, collected by the Ministry of Commerce, (b) information collected by LUD on approved import quantities and importers and licenses issued to fertilizer importers, wholesalers, and retailer/dealers, and (c) data collected by the Ministry of Electricity and Energy on domestic urea manufacture. Routine data analyses are neither performed nor are reports released to provide insight to fertilizer market conditions. This intervention targets improving the availability of fertilizer market information. It is crucial that a centralized database is established with fertilizer data and information to help in policy decision-making and planning as well as to assist the private sector to understand the demand and supply situation in the country. Farmers will also benefit because it will help them plan their activities based on the availability of fertilizers and prices across the country.

10.6.7.1 Theme 7. Monitoring and strategic planning

✓ *Strength the availability of market information on fertilizer supply, farmer use, and prices to support monitoring and strategic planning*

The MOALI is well-positioned to fortify its services to include routine management of fertilizer market information. Coordination of data collection across the various agencies now involved in fertilizer data collection will support a central repository for fertilizer market information. Routine and periodic in-depth analyses and reporting will allow an improved understanding of the fertilizer market situation in Myanmar and the supply and

demand influencing factors that confront farmers. Standardizing data collection, extending data collection to the farm level, and employing statistical methodologies will further market transparency and aid in public/private sector decision-making. Such information, in addition to fertilizer recommendation information, can also be made available via IT channels popular with farmers, such as Facebook and smartphone apps.

✓ *Sensitize all stakeholders on fertilizer-related activities, particularly laws and regulations*
Training workshops and promotions are needed at all levels of the fertilizer value chain to ensure all partners are aware of each other's activities and the existing laws and regulations.

10.6.8 Financial Services for Input Suppliers and Farmers

Fertilizer supply and marketing (import, processing, and stock holding) are capital intensive. For farmers, fertilizers are often the highest cost item of all purchased farm inputs. Financial service providers play a key role in supporting the investment needs of: (a) the private sector in supply and marketing and (b) farmers in procurement of production inputs.

10.6.8.1 Theme 8. Strengthen financial services

✓ *Improve farmers' access to financing through fortified farmer loan programs administered by Myanmar Agriculture Development Bank and Myanmar Livestock and Fisheries Development Bank*
The MADB and MLFDB loan programs provide essential finance. The program enables farmers to buy fertilizers and other essential crop production inputs, including improved seed. However, the loan amount per acre is low (based upon current input costs) and capped at 10 acres per farmer. Also, loan repayment terms require repayment immediately after harvest. Modification of the loan terms to allow for current input costs and delayed repayment to afford farmers flexibility in marketing their crops will render the loan program more market-oriented, with benefits accruing at all levels.

✓ *Strengthen microfinance opportunities through formal service providers and NGOs to support farmer needs*
Improving farmer access to finance through formal systems will further improve technology use. Available options to improve farmer access to financial services are important to long-term development of the fertilizer market and improved soil fertility

management by farmers. Farmers need to understand how they should utilize the loans taken for agricultural purposes from the banks and financial services.

- ✓ *Extend financial services to agro-input dealers*
  Agro-input dealers are starting to establish stronger business linkages with major Myanmar fertilizer companies to gain financial support for fertilizer inventory management. This favorable development is consistent with market-based development in advanced fertilizer markets. In order to stimulate commercial bank loans to agro-input dealers, some large fertilizer companies are engaged in pilot loan schemes to establish the credit worthiness of the small dealers. In the absence of a system that generates routine and official credit reports for individuals, expansion of the pilot credit programs has excellent potential to fill an important void that will accelerate fertilizer market development.

- ✓ *Continue to support contract farming and farmer groups (including farmer cooperatives)*
  As indicated earlier, farmer groups, including private farmer cooperatives, offer an array of benefits to members (e.g., access to finance, fertilizer procurement costs/services, knowledge transfer on GAPs, farm mechanization through custom servicing, crop marketing). NGOs are often effective in group formation and advancing the cooperative form of business. The formation of farmer groups and cooperatives, with increased attention to contract farming, will continue to be emphasized.

10.6.9 Capacity Building

Institutional and human capacity building are vital for Myanmar to advance agricultural transformation. Having well-trained soil scientists, agronomists, and technicians would greatly facilitate the design of best soil fertility and fertilizer management and adaptation measures in the varied agro-ecological zones and to boost agricultural productivity in Myanmar. The government will prioritize investments in human capacity building and institutions that will contribute to strengthened soils and fertilizer research programs, more effective knowledge transfer to farmers, more robust fertilizer quality assurance systems, and improved market transparency over a relatively short time. Capacity building will include establishing a platform(s) that will coordinate the various sector players.

10.6.9.1 Theme 9. Fortify institutional and human capacity building at all levels in the fertilizer sector

Human capacity building to support the SFFMS is a priority in both the public and private sectors. The following are key areas for capacity building:

- ✓ *Department of Agricultural Research*

  The DAR research program is extensive (six research divisions and 17 satellite farms). The DAR divisions are: (1) Rice and Other Cereal Crops Division, (2) Oil Seed Crops and Food Legumes Division, (3) Industrial Crops and Horticulture Division, (4) Soil, Water Utilization and Agricultural Engineering Division, (5) Agronomy, Agricultural Economics and Statistics Division, and (6) Biotechnology, Plant Genetic Resources and Plant Protection Division. Its primary focus is on seed varietal improvement, deferring soil- and fertilizer-related research to the DOA/LUD; this will continue to be the focal area. But to further research benefits/impacts, DAR will intensify linkages with DOA/LUD soil and fertilizer research programs to incorporate ISFM technologies and improved fertilizer products in seed research. DAR capacity building will focus on extension of staff expertise to include soil scientists with fertilizer and soil research expertise.

- ✓ *Department of Agriculture/Agriculture Extension Division*

  The AED plays an essential public sector role in farmer education, including improving farmers' understanding of the factors that contribute to soil degradation and how best to mitigate the causal factors and improve soil management through good agricultural practices. The AED should also play an important role in improving farmer awareness of new fertilizer-related technologies that may improve yields sustainably. Attention to upgrading human capacity with LUD and the extension division will be prioritized. Working closely with YAU to identify weak points in staff knowledge and technology transfer systems, a series of non-degree "short courses" and on-the-job trainings will be designed and conducted for specific subject matter (e.g., soil fertility management, ISFM technologies, fertilizer products, fertilizer use benefits and economic returns, organic fertilizer materials based upon on-farm resources, etc.). Emphasis will also be on increased LUD/AED staff participation in soil fertility and fertilizer workshops and conferences to extend knowledge on new technologies appropriate to soil fertility and fertilizer management.

- ✓ *Department of Agriculture/Land Use Division*

  DOA/LUD soil and fertilizer research programs will be re-oriented to target needs-based priorities. This would entail capacity building in relation to (digital) soil mapping in general and specifically be geared toward generating location-specific fertilizer recommendations to move from Myanmar's blanket fertilizer recommendations to more diversified recommendations. Linkages with seed research programs will be emphasized. Increased attention to the impacts of fertilizers and soil management systems on the environment and soil ecosystems will be an integral component of research programs. The planned research program upgrades will involve expanded research staff expertise (e.g., soil chemistry, soil physics, soil biology) achieved through recruitment of additional research staff and participation of selected staff in post-graduate study programs, sabbaticals (e.g., universities, international agriculture research centers), and workshops and conferences.

  LUD capacity enhancements are also needed in fertilizer quality assurance. Capacity building in the following areas will further strengthen LUD performance: (a) field inspection staff trained in internationally accepted inspection procedures and sampling methods to draw representative samples and maintain security of sample integrity; (b) laboratory staff in the conduct of fertilizer analyses; (c) support staff in administration and registration services; and (d) fertilizer analytical laboratory equipment/materials that will allow for complete fertilizer inspection, sampling, and testing. Human capacity upgrades will be achieved through on-site trainings, staff participation in in-country and international workshops, and study assignments abroad.

- ✓ *Yezin Agricultural University*

  Yezin Agricultural University within the MOALI is the premier agricultural university in Myanmar. The main responsibilities of the university are to: (i) produce highly qualified agriculturalists needed for development of the agriculture sector; (ii) provide adequate technical training on modern methods of agriculture; and (iii) provide practical training to students who wish to engage in scientific farming through cooperatives or private enterprises. For YAU to effectively perform the above functions, there is urgent need to: (i) update the teaching and research curriculum; (ii) continue to collaborate closely with international programs run by the Australian Center for International Agricultural

Research (ACIAR), International Rice Research Institute (IRRI), IFDC, Michigan State University (MSU) etc., in Myanmar; (iii) conduct refresher training of current staff; and (iv) recruit staff for inter- and trans-disciplinary research.

- ✓ *MOALI Agribusiness Information Unit*

  The MOALI will fortify the Agribusiness Information Unit to include (a) routine and ongoing collection of data on fertilizer supply, demand, and prices for inorganic fertilizers by type and commercial organic materials, and (b) periodic (annual) analyses of market conditions and trends. Human capacity needs will include expertise in agricultural economics, statistical analysis, and computer information systems. Linkages with YAU (e.g., Department of Agriculture Economics) and development assistance agencies and projects (e.g., World Bank, LIFT project) will emphasize human capacity building of the scientists and market information specialists.

- ✓ *Agro-input dealer network*

  Strengthening and training agro-input dealers are crucial for improved soil fertility and fertilizer management. Agro-input dealers have direct connection with farmers in disseminating information and technologies. Feedback from agro-input dealers with direct connections to major fertilizer suppliers can help ensure farmer access to the right fertilizer products at the right time. Trained agro-input dealers also can help researchers, extension services, and policymakers strengthen the impact and adoption of fertilizer technologies and practices. They also can fill any void left by public sector extension services. Making modern online tools and smartphone apps available will also aid in this matter.

- ✓ *Coordination*

  Networks are required to coordinate the activities of various actors, leading to faster results to the benefit of all. Mechanisms of collaboration need to be established to engage all stakeholder platforms at all levels.

Figure 4. Schematics of Stakeholder Coordination Platforms

10.6.10 Post-Harvest Markets

10.6.10.1 Theme 10. Strengthen post-harvest markets and improve farmer access to markets

✓ *Agribusiness linkages*

Fertilizer use will improve if farmers see greater returns from its use. Crop price stability (at levels that afford farmers adequate financial incentive to use fertilizers as well as other purchased inputs) and assurance of markets are key to fertilizer demand. Farmer groups and cooperatives provide opportunities for linking farmers to markets and advancing contract farming arrangements. Agribusiness development affords opportunities for contract farming and should be promoted.

✓ *Infrastructure*

Infrastructure development will improve farmer access to markets and contribute to reduced transaction costs. It will also afford farmers access to technologies that impact the preservation of perishable, often high-value crops. Continued emphasis on building farm-to-market roads and linking villages to major market centers, including trading points, should be a priority.

✓ *Gender empowerment*

Approaches to link farmers to post-harvest markets that do not account for gender in terms of access and outcomes are likely to compound existing inequalities. Gender-related barriers to post-harvest markets create income disparities, with men receiving higher income from market linkages. Generally, women face many constraints as they endeavor to engage with market systems. Forming women farmer groups will provide services to their members, including better access to post-harvest market information and collective marketing of farm produce.

11. Compatibility of Soil Fertility and Fertilizer Management Strategy with Key Agriculture Development Strategies

The MOALI priorities for the agriculture sector and strategies for development are embodied in the Agriculture Policy and the Agriculture Development Strategy and Investment Plan draft (GOM, 2016). Among others, the MOALI identifies the key roles for agriculture as ensuring food and nutrition security, increasing foreign exchange earnings, and contributing to rural development. The Agriculture Development Strategy and Investment Plan (ADS) is the document that will guide MOALI strategic activities and investment priorities. It includes five key impact areas, namely: (1) food and nutrition security, (2) rural poverty reduction, (3) agriculture trade competitiveness, (4) higher smallholder farmers' incomes, and (5) farmers' rights ensured and strengthened. The elements of the SFFMS will directly contribute to four of the impact areas through increased agriculture productivity on a sustainable basis, improved yields (quality and quantity) per unit of land area, and improved economic returns to farmers through improved use of high-quality fertilizers.

The SFFMS will complement various other agriculture-related strategies that are in various stages of approval/implementation, including the Rice Sector Development Strategy, Pulses Sector Development Strategy, Climate-Smart Agriculture Strategy, and Myanmar Plant Health Systems Strategy. In order to illustrate, the Myanmar Rice Sector Development Strategy (MRSDS) vision for Myanmar by 2030 is to achieve "food-secure farmers and consumers enjoying the benefits provided by a transformed, dynamic, environmentally sustainable and economically competitive rice sector." The MRSDS is expected to guide the MOALI in decisions related to improvements in the rice value chain. It includes ten

"thematic priorities," which are interlinked. Three of the MRSDS Themes specifically reference fertilizers and the role fertilizers play in environmentally sustainable and economically competitive rice production systems targeted for Myanmar. They are:

- **Theme 1:** *Ensure sustainable increase in rice productivity* – Fertilizer-related priorities addressed in Theme 1 target: (1) ensuring the supply and farmer adoption of appropriate fertilizers, (2) strengthening systems that impact knowledge transfer to farmers on efficient fertilizer use management, (3) strengthening credit availability to facilitate fertilizer purchases of correct type and amount, and (4) ensuring quality control in fertilizers.
- **Theme 4:** *Efficient use and sustainable management of natural resources* – Fertilizer-related priorities addressed in Theme 4 target ensuring the proper application and timing of fertilizer use to (1) increase fertilizer use efficiency and minimize costs and (2) mitigate risks associated with groundwater contamination and greenhouse gas emissions.
- **Theme 6:** *Improve credit scheme and availability* – Fertilizer-related priorities addressed in Theme 6 target improving the current formal credit scheme to enable farmers to increase the rate of fertilizer use by improving their capacity to buy fertilizers.

12. The Way Forward

Improving Myanmar's agricultural soils to support sustainable, high-yield agricultural production systems is an MOALI priority as the country seeks agricultural transformation. It is also a requisite for the success of agriculture-related strategies that have been promulgated, including the Rice Sector Development Strategy and the Pulses Sector Development Strategy. Considerable progress has been made in establishing the foundation for a private sector-based fertilizer supply and marketing system that has demonstrated capacity to: (1) timely service the farmers of Myanmar with a wide range of fertilizer products at internationally competitive prices; (2) introduce new fertilizer-related technologies; (3) contribute to knowledge development on soils-crops-fertilizers; (4) build farmer knowledge on fertilizer use management; and (5) facilitate financing to agro-input dealers to ensure adequate fertilizer supply availability to farmers. Improved collaboration at all levels – public sector (research and extension), private sector (all channel members), and international and non-governmental organizations – is important to timely addressing soil-related issues and the introduction of new technologies to advance Myanmar agriculture.

The progress achieved in the past decade in soil nutrient management through fertilizer use is laudable. But much more can be done in terms of: (1) increasing knowledge of soils and fertilizer requirements, thereby providing a science-based foundation for decision-making on fertilizer requirements; (2) transferring integrated soil fertility management technologies to farmers; (3) establishing systems that underpin fertilizer quality assurance; (4) improving financial service systems targeting fertilizer dealers and farmers; and (5) improving stakeholder access to fertilizer market information. Key SFFMS actions, with target dates for completion, are summarized in Table 14.

Table 14. SFFMS Actions and Targets

Strategic Action	Rationale	Output	Impact	Target Date to Initiate/ Complete
1. Adoption of a site-specific Integrated Soil Fertility Management System for Myanmar that integrates with the existing good agricultural practices	GAPs are already promoted by MOALI. ISFM will fit comfortably into the GAP program and add to the sustainability of farm productivity ISFM will allow farmers to utilize organic and inorganic sources of nutrients, integrated with crop rotations in a whole-farm system The integration of inputs and outputs for total farm productivity and income generation	Farmers utilizing all available sources to maintain soil fertility and farm productivity Input and output value chains working coherently to maximize farm returns without degradation of soil fertility	Farm production and farm income allowing farming as a business opportunity rather than a subsistence lifestyle Empowerment of farmers to make the right decisions to maximize farm production and maintain soil fertility	MOALI commitment To be applied
2. DAR soil and fertilizer research programs strengthened – better linked to modern soil issues, such as sustainability of soil quality, environmental issues associated with fertilizer use, and plant nutrient recommendations	National interests in soil quality status, appropriateness of soil-related technologies inadequately addressed Fertilizer recommendations not current and limited to only 10 crops and one single recommendation per crop for the entire country ("blanket fertilizer recommendation") Soil maps outdated Knowledge improvement of environmental impacts of soil fertility management practices	Increased knowledge and understanding of Myanmar soils, key soil-related challenges that impact sustainability of agriculture and opportunities identified for improving soils National soil map geared toward improving fertilizer recommendations developed jointly with LUD-DOA Updated and expanded fertilizer recommendations based on ISFM practices – all crops by agro-ecological zone, taking the national soil map as a basis and validating the fertilizer recommendations generated by the map in field trials Making recommendations available using modern dissemination techniques (online and smartphone apps) in addition to traditional ones	Provide foundation for soil management strategy Improve farmer use of fertilizers/improved agricultural productivity Collaborative opportunities with IARCS, university systems, others on soil management Environmental awareness improved on soil management and fertilizer use Updated information available to farmers through agro-input dealers/retailers, government extension staff, and private sector Improved product mix of fertilizer importers/processors based upon updated crop- and zone-specific requirements	In progress - continuing

Strategic Action	Rationale	Output	Impact	Target Date to Initiate/ Complete
3. AED field programs strengthened – technology demonstrations, farmer field days, farmer education programs	Farmer knowledge of fertilizer use is low Agro-input dealers have limited advisory capacity to educate farmers The above two factors contribute (in part) to low and unbalanced use of fertilizers New technologies entering the market not well-understood by agro-input dealers and farmers	Farm-level fertilizer technology demonstrations within the ISFM framework Farmer field days Farmer and agro-input dealer education programs Fertilizer quality improved	Farmer knowledge increased on GAPs Agro-input dealers better linked with knowledge source, increasing capacity to advise farmers on fertilizer use management and most cost-effective products for crops in specific zones New technologies validated under Myanmar farmer conditions and rapidly introduced	In progress - continuing
4. Financial service systems targeting value chain members developed	Agro-input dealers have limited access to finance for working capital in fertilizer	Financial services strengthened, providing quality loans to support vibrant fertilizer business community	Improved inventory management by agro-input dealers Agro-input dealers' profitability improved and sustained	In progress - continuing
5. Financial service systems targeting farmers' crop production requirements fortified	Farmers unable to self-finance fertilizers MADB crop loan program limited in loan value and restrictive in repayment requirements, limiting farmer flexibility in crop marketing	Financial services to farmers enhanced – loan amount, repayment terms	Farmers procure needed inputs to support adoption of improved technologies Farmers' flexibility in crop marketing expanded	2018 - continuing
6. Market information systems developed	Serious lack of accurate and timely information on fertilizer markets	Regular/periodic reports on fertilizer market – farmer use of fertilizer by type/crop/season and by zone/region and state, fertilizer supply by import type and source, domestic manufacture/processing, local retail prices in key markets All fertilizer retailers documented	Improved policy decisions Improved decision-making by private sector	2018 - continuing
7. Collaboration/ information dissemination – public-private international organizations-NGOs	Limited information exchange constrains knowledge transfer Inconsistent messaging to farmers	Improved information flows – research linked to market issues, information dissemination emphasized Making all information available using modern dissemination techniques (online and smartphone apps) in addition to traditional ones	Capacity building at all levels in value chain, including farmers and agro-input dealers Improved appraisal/introduction of improved technologies	2018 - continuing
8. Fertilizer supply strengthened	Imports of fertilizer are attractive based upon near- and medium-term supply and price outlook Myanmar's close proximity to major fertilizer suppliers offers trade advantages Value-added domestic processing offers potential benefits in tailoring fertilizers to specific soil and crop requirements based upon favorable economies Domestic ammonia urea factories uneconomic vis-à-vis imports Uncertain capacity of fertilizer processors/bulk-blending companies in making multi-nutrient products Uncertain quality control systems at processor/bulk-blending company level	Cost-effective supply system for fertilizers established and responsive to opportunities for technology improvement Improved targeting of specific fertilizer grades to crops/zones, resulting in improved crop yields and economic returns to farmers Complete training of operators in fertilizer processing/blending to achieve high-quality fertilizer blends – basics in processing/blending technology, problem identification in fertilizers, sampling and testing to support quality assurance	Timely availability of internationally price-competitive fertilizers Improved fertilizer product mix Fertilizer quality improvement for locally processed/bulk-blended fertilizers at processing point	In progress - continuing

Strategic Action	Rationale	Output	Impact	Target Date to Initiate/ Complete
9. Fertilizer Marketing System Private sector capacity – agro-input retailers in farmer advisory services, detection of fertilizer quality issues, quality control systems in inventory management Private sector capacity – import/wholesale-level actors in import procurement management, international standards for fertilizer specifications, and quality control Private sector – fertilizer processors/ blending	Vibrant private sector now engaged in fertilizer market development, knowledge development, fertilizer supply assurance to Myanmar farmers Knowledge of international fertilizer import procurement management to ensure quality Knowledge of fertilizer quality detection limited Poor capacity to provide fertilizer advisory services to farmers	System continues to evolve with improved delivery of fertilizer grades to meet soil/crop requirements, extension of agro-input dealer networks, increased dealer advisory capacity/technology transfer to improve farmer knowledge/introduce new technologies Complete training of agro-input dealers in basics of crop nutrient management, fertilizer products and best use practices, nutrient deficiency symptoms in crops, fertilizer storage methods, fertilizer quality control, and identification of quality deficiencies Upgrade knowledge in import procurement management – emphasis on quality control: fertilizer technical specifications, bagging, independent inspection services, etc.	Improved fertilizer use management by farmers due to increased knowledge transfer on best use practices Improved crop yields Balanced fertilizer use supports sustainability of soil's productive capacity Fertilizer quality improved with better detection of quality issues at retail/dealer point of sale	In progress - continuing
10. Fertilizer Law/Regulatory System	Definitions incomplete/ nonconforming with international standard Poor clarity in language Insufficient details on accepted values – bag weight, nutrient content, penalties	Fertilizer Law upgraded to international standard – complete set of definitions, clarity in language, and specifics regarding nutrient and bag weight tolerance limits and penalties for violations	Improved stakeholder awareness of legal requirements related to fertilizers and consequences of violations Solidified foundation for fertilizer quality	2018 - 2019
11. LUD capacity – functional performance	LUD analytical capacity inadequate LUD operations manual not available – using the dated Fertilizer Control Order of India Manual to guide operations Fertilizer inspections not performed at adequate level in key points in value chain Inspection/sampling methodologies deficient No fertilizer laboratory operations manual specific to Myanmar No testing capacity at major point of entry for fertilizer imports (Muse) Mandalay lab not fully equipped for micronutrient analyses Fertilizer inspector knowledge uncertain	Continue with product registration formalities in current approach; strengthen systems through routine and ongoing inspections at point of entry for imports, processor/blender sites, and at sales points in the market Develop fertilizer inspection manual to guide field inspectors Develop LUD fertilizer analytical laboratory operations manual, compliant with reformed Myanmar Fertilizer Law and in conformity with internationally accepted methodologies for fertilizer analyses and laboratory safety standards Establish fully equipped LUD fertilizer laboratory in Mandalay and at key border import entry point (Muse) Complete training of LUD laboratory analysts and field inspectors. Conduct capacity building of LUD-DOA in relation to (digital) soil mapping and generating from that site-specific fertilizer recommendation domains	Fertilizer Law enforced Improved fertilizer quality Restored stakeholder confidence in fertilizer quality Improved functioning of fertilizer market with reduced violation of fertilizer product "truth-in-labeling" concept Clarity in analytical methodologies and laboratory procedures for current and new fertilizer products Improved safety awareness/safety protocols in laboratory	2018 - continuing

Strategic Action	Rationale	Output	Impact	Target Date to Initiate/ Complete
12. Myanmar Fertilizer, Seed and Pesticide Entrepreneurs Association	Excellent potential to: a. Represent private sector interests in fertilizer-related issues b. Support technology transfer to build dealer/farmer capacity c. Liaise with MOALI DOA and AED, university systems, IARCS, NGOs on fertilizer-related challenges/opportunities	Fertilizer Dealer Handbook Policy dialogue with government/ private sector representation Improved market information flows Annual conference to introduce technologies, research findings, global trends in fertilizers Newest findings also made available online and via smartphone apps	Agro-input dealer capacity to advise farmers increased Fertilizer-related policy issues collaboratively addressed	In progress - continuing

The rollout of this strategy will require a concerted effort from both the public and private sector and, within the public sector, from policy, regulatory, research, and extension professionals. Coordination will be the key, and Figure 4 provides a schematic of the actors in a coordination network. Consideration should be given to establishing a coordinating body with public and private sector representation.

Section 10.4 defines the strategy's targets; by 2030: 80% of the cultivated land in Myanmar will have site-specific fertilizer recommendations for all crops grown; 100% of farmers will have access to the knowledge required for integrated soil fertility management for their farm; and 100% of farmers will have access to high-quality fertilizer products that are appropriate for ISFM. Given the limited capacity in extension and research, the best approach to start would be a pilot project, perhaps linked to the five new Regional Research Centers that DAR is establishing jointly with DOA to implement a farming systems research approach. This could be used to learn lessons and gain experience and capacity for a nationwide rollout to follow.