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Nutrient Stewardship and Sustainable Fertilizer Use

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Background

Mineral fertilizers have played a major role in global agricultural production, with more than half the total crop yields attributed to nutrients from fertilizer. Over the past century, fertilizer use has been a key factor in sustained increase in crop productivity, which has anchored economic and social development, and reduced the need to clear forests for agricultural use (Tilman et al., 2002). Despite this progress, nearly one billion people remain undernourished (FAO, IFAD, UNICEF, WFP and WHO, 2017). In addition, the global population is projected to reach to 10 billion by 2050, which presents major challenges to increase crop productivity not only meet growing food demands, but also to increase food quality while minimizing the adverse effects on the environment. Demands for both fertilizers and agricultural land are expected to accelerate against the backdrop of increased pressure for scarce land, energy and water resources. A major dilemma for future agricultural development is that the largest increase in population is projected to occur in Africa and South Asia, regions that are already experiencing the largest food deficits and major environmental problems, and are also the most severely affected by climate change (FAO, 2017).

Fertilizer use, use efficiency and sustainable crop production intensification

The targets for crop productivity increase to meet current and future food security needs will be elusive without the effective and efficient use of fertilizer nutrients. Despite contested definitions for the concept of sustainable intensification, there is consensus for the critical role of management practices that are geared to achieve the delicate balance between increasing productivity on existing cropland, sparing expansion into native grasslands and forests, minimizing negative environmental effects and maintaining soil health and ecosystem services (Petersen and Snapp, 2015). Nutrient Use Efficiency (NUE) is an important parameter for evaluating performance and sustainability of crop production systems (Fixen et al. 2015). NUE indicates the potential for nutrient losses to the environment from cropping systems as farmers strive to meet the increasing societal demand for food, feed, fiber and fuel. Effective and profitable nutrient use puts increased emphasis on high efficiency. The greater nutrient amounts that higher yielding crops remove means that more nutrient inputs will likely be needed and at risk of loss from the system. Therefore, both productivity and NUE must increase. Sustainable nutrient management must be both efficient and effective to deliver anticipated economic, social, and environmental benefits.

Analysis of historical crop yield and fertilizer use trends across global regions show a close correlation between economic development and NUE in three distinct phases (Zhang et al., 2015). The initial phase typical for very low income countries is characterized by extremely low fertilizer use that result in negative soil nutrient balances, as the amounts of nutrients applied are insufficient to offset nutrients removed by crops. Many countries in sub-Saharan Africa not only face large food deficits, but also experience major land degradation and nutrient depletion problems that are triggered by low fertilizer use.

Increasing income enables demand for more food consumption, which increases the intensity of agricultural production and consequently results in more nutrients losses to the environment. In the second phase, the greatest emphasis is placed on increasing fertilizer use as the main driver for increasing productivity, which is often achieved with the penalties of reducing NUE and increasing negative environmental consequences. This phase is currently a major challenge in several middle income countries, such as India and China, and has been experienced in the past in many developed countries (Lassaletta et. al., 2014).

Further along the trajectory of economic development, improved access to advanced technologies and increased demand for improved environmental quality lead to a third phase in which productivity and NUE are concurrently increased. Improved nutrient management in this phase is also often driven by government regulatory policies or incentives targeted at reducing negative environmental impacts. The trend towards sustainable intensification in the third phase depends largely on holistic systems-level best management practices for soil, crops, nutrient and water that include the use of improved and adapted crop varieties, improved water management, balanced nutrient application, precision crop and fertilizer management and and the use of enhanced-efficiency fertilizers (Ciampitti and Vyn, 2014).

The 4R Nutrient Stewardship

The 4R Nutrient Stewardship framework was developed by the fertilizer industry as a process to guide fertilizer Best Management Practices (BMP) in all regions of the world (PNI, 2012). It enables the industry to clearly articulate the effort and goals for sustainable fertilizer use to various stakeholders, including the farmers, policy makers and the general public. Given that fertilizers constitute the largest input investment cost in most regions, most farmers are cautious about the economic viability of fertilizer use. The 4R Nutrient Stewardship offers opportunities to improve nutrient use efficiency and environmental sustainability, while supporting the profitability of farms (Johnston and Bruulsema, 2014).

The 4R Nutrient Stewardship provides a simple, practical and actionable framework to enable the development of holistic and effective nutrient management recommendations that match crop nutrient requirements and fertilizer additions, and minimize nutrient losses from fields. It is based on global scientific principles that are used to develop guidelines for effective nutrient management practices at the local level by applying the Right Source of nutrients, at the Right Rate, at the Right Time and in the Right Place. Right source means matching the fertilizer to the crop need and soil properties. A major part of source is the balance between the various nutrients, a major challenge globally in improving nutrient use efficiency. Additionally, some fertilizer products are preferred to others based on the soil properties, such as texture and pH. Right rate means matching the fertilizer applied to the crop need. A major focus of the right rate is to strike a balance between the crop needs, environmental conditions and the farmers economic situation. Right time means making fertilizer nutrients available to the crop when they are needed. Nutrient use efficiency can be increased significantly when their availability is synchronized with crop demand. Split time of application, slow and controlled release fertilizer technology, stabilizers and inhibitors are examples of how fertilizer nutrients can be better timed for efficient crop uptake. Right place means making every effort to keep nutrients where crops can use them. This is an issue which poses the greatest challenge in small holder agricultural systems, where most fertilizer is broadcast applied, and in many cases without incorporation. Research indicates that fertilizer placement can not only improve crop response, but also improve fertilizer use efficiency significantly by lowering nutrient application rates.

While the scientific principles that guide the definition of 4R practices are generic and universal, their application in various regions are context- and site-specific and require adaptation to suit the farming system, socio-economic and biophysical conditions. In low income regions dominated by smallholder farms such as sub-Saharan Africa, 4R priorities should focus on supporting farmers to increasing fertilizer use, regional recommendations for balanced fertilizer use and building farmer knowledge on best practices for simple and cost-effective fertilizer placement and application timing practices. In middle income countries such as India, efforts to support adoption of site-specific fertilizer recommendations and policies to encourage balanced nutrient application are essential for enhancing the impact of 4Rs. In the context of developed countries such as the USA, there is scope to improve the implementation of 4Rs by further developments in advanced precision nutrient management technologies. The South African Agriculture sector requires a dual 4R development system to advance high technology 4R solutions tailored for the well-developed and diverse commercial crop production sector, and simple technologies for the smallholder sector. Across both sectors, there is need to focus on technologies for soil and water conservation to optimize nutrient and water use efficiency under the prevailing patterns of increasing droughts. Globally, emerging scientific innovation such as high resolution geospatial information mapping and analytic tools, improved weather prediction and soil water measuring technologies, rapid and cost effective soil fertility diagnostics using spectroscopy based tools, fertilizer nanotechnology and bio-stimulants will provide windows of opportunity for further gains in crop productivity and fertilizer use efficiency.

4R Nutrient Stewardship capacity building

For any given crop production system, stakeholders need to define the social, economic and environmental goals that determine the suitability of 4R technologies. Decision making in selecting the best practices suited to local site-specific soil, weather, and crop production conditions, and local regulations must be supported by adequate knowledge of 4Rs; hence the need for capacity building and knowledge dissemination to key stakeholders. Ultimately, farmers are best placed to choose the practices, and equipping them with the right decision support information and tools offer the best prospects for adoption of 4Rs to enable effective use of fertilizer for sustainable crop production intensification.

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