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Fertilizer Management: Soil Health Effects

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Where the supply of nutrients in the soil is adequate, crops are more likely to grow well and produce large amounts of biomass. Fertilizers are needed in those cases where nutrients in the soil are lacking and cannot produce healthy crops and sufficient biomass. There are four management objectives associated with any practical farm level operation, including management of fertilizers. These are productivity, profitability, cropping system sustainability, and a favorable biophysical and social environment. Sustainability refers to the medium- and long-term effects of fertilizer management options to maintain or increase the productivity and profitability of the cropping system. Indicators include trends through time in yield, input use efficiency, soil parameters such as N supplying capacity, the presence of organic matter, and profitability. Best management practices for fertilizer support the realization of these objectives in terms of cropping and the environmental health. A strong set of scientific principles guiding the development and implementation of fertilizer best management practices has evolved from a long history of agronomic and soil fertility research. When seen as part of the global framework, the most appropriate set of fertilizer best management practices can only be identified at the local level where the full context of each practice is known. Nutrient stewardship is the efficient and effective use of plant nutrients to achieve economic, social and environmental benefits with engagement from farmers and other stakeholders. This concept essentially describes the selection of the right source of nutrients for application at the right rate, at the right time, and in the right place. Specific and universal scientific principles that apply to these four areas of management are applicable at the farm level. However, the application of these scientific principles may differ widely depending on the specific cropping system, the particular region and the crop combination under consideration. As a practice, nutrient stewardship is dynamic and evolves as science and technology expands our understanding and opportunities; practical experience teaches the astute observer what practices work or do not work under specific local conditions. Decision-support systems guiding the adoption of fertilizer best management practices require a dynamic process of local refinement. Therefore, involvement of individuals knowledgeable in both scientific principles and local conditions is important to this process.

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As soils are at the heart of several sustainability issues facing humanity, management of fertilizers in cropping systems following principles of nutrient stewardship is the best approach to ensuring improvement in soil health due to application of fertilizers for crop production. There are several causes of the declining or lower crop responses to applied fertilizers or efficiency of fertilizer applications in several developing countries. One major cause of this decline is the continuous nutrient mining of the soils (particularly P, K, sulphur (S) and micronutrients) resulting from unbalanced fertilization practices which eventually leads to unhealthy soils and plants. Therefore, fertilizers should be applied in sufficient quantities and in balanced proportions. The efficiency of fertilizer use is likely to be high where the organic matter content of the soil is also high. In unhealthy or depleted soils, crops use fertilizer supplied nutrients inefficiently. Where soils are highly degraded, like in parts of india, crops hardly respond to fertilizer applications. When SOM levels are restored, fertilizer can help maintain the revolving fund of nutrients in the soil by increasing crop yields and, consequently, the amount of residues returned to the soil. In a long-term experiment, the highest organic matter content in the soil has been observed in plots to which N, P and K were applied in a balanced proportion. In treatments receiving only N or inadequate amounts of P and K, there was a decline in soil health.

Site-specific nutrient management

Weather based on nutrient status of soil or plant in a given field, ensures that nutrients applied via fertilizers are managed according to the needs of the soil-plant system. Thus, as compared to blanket fertilizer recommendations for different crops, which are still prevalent in several developing countries, site-specific nutrient management ensures that soil health is maintained on a long-term basis.

EXCESS FERTILIZER USE: POTENTIAL SOIL HEALTH DETERIORATION

A sustainable soil health management system, which has the capacity to produce higher yields while using fewer external inputs, can be achieved by a combination of ecosystem processes and appropriate use of fertilizers. Figure 2 shows differences in nutrient inputs and outputs at three locations representing under-use, over-use and adequate use of fertilizers. The N outputs at the indian site are much larger than the inputs, leading to substantial nutrient depletion or “soil mining” and consequent long-term degradation of soil health. On the other hand, high fertilizer nutrient inputs in China greatly exceed nutrient outputs and point towards substantial risks of nutrient losses to the environment. With almost similar inputs and outputs of both N and P, soil health in the Midwest USA is better than in either the indian or Chinese sites. Soil quality is affected by nutrient availability as well as the potential for nutrients to degrade the environment. As soils represent a major store of reactive forms of nutrients, their sound management is critical to address global food security challenges as well as to minimize nutrient losses to the environment that can impact air and water quality. The other threats to soil health are many and varied : soil compaction, erosion, acidification, salinization, contamination, and organic matter decline, most of which can influence N and P losses to water and air. Soils contain variable amounts of nutrients, which are needed by plants, animals and humans. Almost all nutrients in plants are taken up by roots from the soil, and primary production in many natural environments and agro-ecosystems is strongly limited by the availability of nutrients. This is especially the case in highly weathered and leached soils such as in large areas of Africa, Latin America, and Australia. Shortage of nutrients in soils leads to low crop yields and also to low contents of nutrients in the harvested crop; the sub-optimal nutrient concentration in crop produce may lead to malnutrition of animals and humans. The elements N and P are often the most crop yield-limiting nutrients in agricultural soils. Most of the N is not directly available as it is organically bound although many irrigated soils with low SOM content can have much of the N in inorganic form in the profile. Most of the P is either organically bound or bound to iron or aluminium compounds, e.g., oxides and oxy-hydroxides. Soils require a certain minimum level of plant-available N and P and other essential nutrients to fulfil the soil functions of food, feed and fibre production. However, a surplus supply of reactive N and P threatens the quality of the soil and results in the emissions of ammonia and N oxides to the air and loss of nitrate and P to water bodies . Excessive inputs of reactive N and P affect the quality of soils under forests and natural vegetation far more than that of agricultural soils. As a consequence, relatively small inputs of reactive N and P lead to surpluses in forests and natural vegetation. Also, agricultural soils, unlike soils under forests and natural vegetation, are managed ones so that their disorders tend to be corrected even if the corrections are not always cost-effective. Application of excessive inputs of fertilizer P leads to the build-up of soil P to the point that the sorption capacity of the soil is eventually ‘saturated’. The build-up of soil P can lead to increased losses of P to surface waters through overland flow, erosion and subsurface leaching and drainage. In Sub-Saharan Africa, and in some other developing countries, soil health concerns, in as much as they are articulated, are due to poor nutrient supply in the soil. Two main factors underpin this concern. Firstly, increasing population pressures on agricultural land leads to a breakdown of traditional practices, resulting in much higher nutrient outflows. Secondly, there is generally a policy environment that does not give sufficient support to the small farmers to implement soil and cropping practices that could potentially reverse this depletion. A consequence of poor soil health is the high prevalence of food and nutrition insecurity due to lower agricultural production, less fodder for cattle, less fuel wood for cooking, and less crop residues and cattle manure to recycle nutrients to soils. Additional CO2 emissions to the atmosphere are observed from decreasing soil and plant C stocks associated with soil nutrient depletion and deforestation. Also, in some soils, SOM levels have dropped even to a threshold below which crop response to other inputs is very poor.