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Site specific nutrient management: A review

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Abstract
Site Specific Nutrient Management (SSNM) is an approach of supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients by using different tools of SSNM such as remote sensing, GPS, GIS systems, VRT, yield monitoring. In horticultural crops, under-fertilization may result in a yield loss and over-fertilization can be harmful to the environment. With the invention of SSNM, it has become possible to manage soil nutrient variations throughout a field with prescription fertilizer applications. Stress management is another area where SSNM can help Indian farmers. Most cultivated soils in India are acidic, whereas spatial variation in pH is high. Detecting nutrient stresses using remote sensing and combining data in a GIS can help in site-specific applications of fertilizers and soil amendments. This in turn would increase fertilizer use efficiency and reduce nutrient losses. SSNM in India is in its infancy but there are numerous opportunities for adoption. The technology has the potential especially in the high value crops. Effective coordination among the public and private sectors and growers is, therefore, essential for implementing new strategies to achieve fruitful success.

Keywords: Site specific, nutrient, fertilizers, spatial temporal

Introduction
To feed growing population, India will have to produce more and better food from less land. In order to meet all objectives of sustainable agriculture (increased food and fibre, profitability, efficiency of input use and an appropriate concern for the environment), a balance of adequate levels of nutrients is the key component. Over the past four decades crop management in India has been driven by increasing use of external inputs. Fertilizers have played a major role in improving crop productivity. Food grain production were more than doubled from about 98 million tonnes (MT) during 1969-2007 to a record 212 MT in 2001-2002, while fertilizer nutrient use increased by nearly 12 times from 1.95 MT to more than 23 MT in 2007-08 (Rao, 2009) [5]. Notwithstanding these impressive developments, food grain demand is estimated to increased about 300 MT yr^{-1} by 2025 for which country would require 45 MT of nutrients (ICAR, 2008) [2]. With almost no opportunity to increase the area under cultivation over 142 million hectare, much of the desired increase in food grain production has to be attained through yield enhancement in per unit area, in particular that of major staple food crops like rice, wheat and maize, which incidentally responded considerably to the introduction of green revolution technologies to contributing to more than 80% of total food grain production (Johnston *et al*. 2009) [3].
At the all India level, soil deficiencies of N, P, K, S, Zn, and B are now of widespread importance. Nitrogen deficiency is common in the vast Indian plains. Potassium fertility of soils is not only neglected, but is also under severe stress with the ongoing scenario where K removal vastly exceeds K input. Sulphur deficiencies are now estimated to occur in close to 250 districts and about 40% of soil samples have been found to be S deficient. Based on several years of data and 2,50,000 soil samples, 49% of soils have been found to be deficient in Zn, 12% for Fe and less than 5% for Cu and Mn. Boron deficiencies in several areas with 33% out of 36, 800 soil samples analyzed having been found to be B-deficient (Singh, 2001) [6]. Nutrient differences which exist within fields, and making adjustments in nutrient application to match these location or soil differences by using some form of field diagnostic, such as intensive soil sampling, soil sensing, aerial imagery, yield mapping etc. is known as Site specific nutrient management (SSNM). Site-specific management allows for fine-tuning crop management systems along with 4R Nutrient Stewardship the right source, rate, time and place of nutrient use.

Concept and approaches
Site specific nutrient management (SSNM) is an approach of supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients.

The SSNM provide an approach for need based 'feeding' of crops with nutrients. The SSNM approach aims at increasing farmers' profit by achieving the goal of maximum economic yield (MEY) of crops. The main features of SSNM are: (Tiwari, 2007) [8]

- Site specific application of nitrogen, phosphorus and potassium and secondary and micronutrients based on soil tests are followed.
- Optimal use of existing nutrients, such as from soil, residues and manures.
- SSNM further provides guidelines for selection of the most economic combinations of nutrients.
- Advocates wise and optimal use of existing indigenous nutrient sources such as crop residues and manures.

The introduction of SSNM strategies should start with the priority areas facing one or more of the following problems: (Tiwari, 2007) [8].

- Ares having inadequate or unbalanced use of fertilizer nutrients with low yield levels.
- Areas with showing nutrient deficiency symptoms on large scale.
- Areas with occurrence of pest problems linked to nutrient imbalance or overuse of fertilizer N.
- Areas with inefficient fertilizer N use at higher rates (no proper splitting and timings) with in sufficient use of P and K.
- Areas with the evidence of large mining of phosphorus and potash reserves of the soil.
- Areas having evidence of multi-nutrient deficiencies including secondary and micronutrients in soils and crops.

Elements of SSNM

Site-specific management technology relies on the interaction of three broad and fundamental elements to be successful in its implementation. They are categorized in terms of information, technology and management.

Information

In field variability, spatially or temporally, soil related properties, crop characteristics, weed and insect pest population and harvest data are important databases that need to be developed to realize the potential of site-specific management technology. Out of these, crop yield monitoring is the most mature component and logical starting point. Several years of yield data may be required to make a good decision. Highly varying yield within field indicates that the current management practices may not be providing the best possible growing conditions everywhere in the field.

Establishment of soil related characteristics within field, through regular soil sampling, is another database that is extremely important. Some of the characteristics such as soil texture vary very little over time, others such as moisture content and nitrate level, fluctuate rapidly. Decision therefore, has to be made on what property to sample, how to sample and how often to sample so that interpretation from database can be made with greater confidence.

Technology

The recent development in microprocessor and other electronic technologies for monitoring yields and sensing soil related variables are new tools available to make site specific farming a success. When measuring soil characteristics such as the harvest data, moisture and nutrients availability in the soil, satellite based positioning system, namely, geographical positioning system (GPS) can be used to identify the locations where the data are taken. Some GPS users demand accuracy in identifying field location and differential global positioning systems (DGPS) is one of the improved GPS system that reduce position errors. With this information, the results of soil sampling test and yield data can be transformed in to field maps, achievable through personal computers (PC) and geographic information systems (GIS) software. The same map can be developed for other field characteristics such as weed and salinity mappings. Remote sensing technique can also be utilized to detect soil related variables, pest incidence and water stress. The basic idea of site specific farming is not only to measure field variability, but also to be able to apply inputs at varying rates almost instantaneously, "real time", according to the needs. Variable rate application machinery is a type of field implements that could be used to handle field application of inputs such as seed, fertilizer and pesticides at the desired location in the field, at the right amount, at the right time and for the right reasons. The application of variable rate technology (VRT) can be accomplished either as a map based VRA or a sensor based VRA. However, different types of sensors are now available (or under development) that can monitor crop yield, soil properties, and crop condition that can be used to controlled field operations.

Management

Site specific farming makes farm planning both easier and more complex. The ability to combine information generated and the existing technology into a comprehensive and operational system is the third key area in the precision farming. A farmer must adopt a new level of management proficiency on the farm. Implicit in this is an increased level of knowledge of precision farming technologies such as GPS and GIS, better understanding of soil types, microclimates, aerial photography, economics of farming for accurate assessment of risk based on different decisions.

The availability of yield map, weed distribution map, soil map, nutrient status map, water/ moisture availability map, pest and disease incidence map etc. require the farmer to make decision on how to treat the field for optimum or maximum yield. From this information, a treatment map or a DSS (Decision support system) can be developed utilizing GIS, agronomic, economic and environmental software, to help the farmer manage his field. The real values for a farmer is that he is enabled to easily and confidently manipulate seeding rate, plans more accurate crop protection and fertilizer application programmes, performs more timely tillage and knows the yield variation within a field. This precise micromanagement of his farming enterprise will enhance the overall cost effectiveness of precision farming in crop production.

SSNM is likely to provide a greater profitability advantage for (a) high value crops, (b) areas where input cost are high and (c) areas where production conditions are very heterogeneous.

Basic steps in SSNM

Assessment of soil and crop variability, managing the variability and its evaluation are three basic steps in site specific nutrient management. The available technologies enable us in understanding the variability and by giving site specific agronomic recommendations we can manage the variability that make precision farming viable and final evaluation must be an integral part of any precision farming system.

Assessing variability

Assessing the variability is the critical first steps in precision farming. Quantifying the variability of the factors and processes and determining when and where different combinations are responsible for the spatial and temporal variation in crop yield is the challenge for the precision farming.

Techniques for assessing spatial variability are readily available and have been applied extensively in precision farming. The major part of precision farming lies in assessing the spatial variability. Techniques for assessing temporal variability also exist but the simultaneous reporting of spatial and temporal variation is rare. We need both the spatial and temporal statistics. We can observe the variability in the yield of a crop in space but we cannot predict the reasons for the variability. It needs the observations at crop growth and development over the growing season, which is nothing but the temporal variation. Hence, we need both the space and time statistics to apply the precision farming techniques. But this is not common to all the variability/ factor that dictate crop yield. Some variables are more produced in space rather with time making them to more conducive to current form of precision management.

Managing variability

Once variation is adequately assessed, farmers must match agronomic inputs to know conditions employing management recommendations. Those are site specific and accurate use applications control equipment. We can use the technology most effectively, in site specific variability management. While taking the soil/plant samples we have to note the samples site coordinates and further we can use the same for management. This results in effective use of inputs and avoids any wastage.

The potential for improved precision in soil fertility management combined with increased precision in application control make precise soil fertility management as attractive, but largely unproven alternative to uniform field management. For successful implementation, the concept of precision soil fertility management requires that, within field variability exists and is accurately identified and reliable interpreted and influences crop yield, crop quality and the environment. The higher the spatial dependence of manageable soil property, the higher the potential for precision management and the greater its potential value. The degree of difficulty, however, increases as the temporal component of spatial variability increases. Applying this hypothesis to soil fertility would support that phosphorus and potassium fertility are very conducive to precision management because temporal variability is low. For N, the temporal component of variability can be larger than its spatial component, making precision N management much more difficult in some cases.

Evaluation

There are three important issues regarding precision farming evaluation: economics, environment and technology transfer. The most important fact regarding the analysis of profitability of precision farming is that the value comes from the application of the data and not from the use of the technology. Potential improvements in environmental quality are often cited as a reason for using precision farming. Reduced agrochemical use, higher nutrient use efficiencies, increased efficiency of managed inputs and increased protection of soils from degradation are frequently cited as potential benefits to the environment.

Components of SSNM

Global positioning system (GPS)

Global positioning system, contains 24 orbiting satellites emitting radio signals that allows the GPS receivers to capture their location. Having precise information at any time allow soil and crop measurement to be mapped. GPS receivers, either carried to the field or mounted on implements allow users return to specific location to sample or treat those areas. The precise locating is necessary to the data capture and farming operation in precision farming. In case of crop production, many operations are executed in terms of the internal diversity in every field plots such as the precise seeding, fertilizing, irrigating, and controlling of plant diseases, insect pests, and so on. The use of GPS in Agriculture is limited but it is fair to expect wide spread use of GPS in future. Recently a GPS-based crop duster (precision GPS Helicopter) which can spray an area as small as 4 × 4 meter is attracting great attention. Some progressive farmers are now beginning to use GPS for recording observations. In the years to come, GPS system role in precision agriculture may help the Indian farmers to harvest the fruits of frontier technologies without compromising the quality of land and produce.

Remote sensing

Remote sensing is collection of data from distance. Data sensors can simply be hand held devices, mounted on air craft or satellite based. Remote sensing technique is the key technique to acquire the field information in precision agriculture, and it can provide the interior details of field plot for decision-making of precision agriculture as the habits of crop growth, the status of crop growth, and the information of spatial variability. The technique of agricultural remote sensing was trended gradually to comparative perfect in last 30 years. It is of powerful potentials to apply in many fields such as the monitoring of soil moisture, monitoring of crop nutrients, monitoring of crop pest and disease, monitoring of crop growth status, yield estimation of crop etc. and serve as an important resources of information to precision agriculture. This is for Data acquisition of the farms to find the soil, vegetation and other parameters that are amenable for remote sensing.

Geographic information system (GIS)

GIS are computer hardware and software system that use feature attributes and location data to produce map. An important function of agricultural GIS is to store layers of information, such as yield, soil survey maps, remotely sensed data, etc. This platform goes hand in hand with other systems or users by the exchange of information. In general, the information service includes mostly the service of information management, the service of message exchange and update, the service of decision analysis, and the service of information release.

Yield monitoring

Yield monitoring and mapping are key elements of site-specific farming and they were the most widely used components of precision farming initially (Heacox, 1998) [1]. Yield monitoring offers the most intensive measure of spatial yield variability that exists in farm fields, allowing producers to assess how management skills and environmental factors effect crop production (Stombaugh and Shearer, 2000) [7]. This assessment provides direct and valuable feedback to the farmer enabling them to make better management decisions (Pelletier and Upadhyaya, 1999) [4]. Such feedback includes but is not limited to: instantaneous yield and moisture documentation, creation of yield and moisture maps, digitally flagged pest documentation and organization of data by year, farm, field, load, and crop. Yield monitoring over time creates a unique GIS database that assists farmers to easily identify yield variability within a field, to make better variable-rate decisions, and to create a history of spatial field data. This technology is being researched and commercialized for other crops such as potato, onion, sugar beet, tomato.

Variable rate technologies (VRT)

Variable-rate technology (VRT) is used to adjust the agricultural inputs according to the site-specific requirements in each part of the field. If machines are used, this requires variable-rate machinery. On small farms, inputs can be applied manually. Variable-rate applications need: a) Correct positioning in the field; b) Correct information at the location; and c) Farm machinery equipped with VRT controllers which typically have a DGPS receiver to identify the precise location of spatial variability in the field and automatically control the rate of application based on pre-derived input application maps. There are various applications of VRT technology in site-specific cropping systems management. Variable-rate application equipment is perhaps the most widely used precision agriculture technology. About 1,600 flotation fertilizer-application systems, map-driven variable-rate technology (VRT) systems, and on-the-go sensor tractor-based application systems have been sold.

Conclusion

The concurrent engineering in biology, mechanics, electronics and other areas is the main course for developments. This is a unique challenge to deliver creative work based on knowledge of the living and non-living material. The results of such an effort can be site specific nutrient management in agriculture whereby products with a precisely described quality are grown and supplied to the market using precision techniques during growth, harvest, storage and handling.

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