PRECISION FARMING

Soil Fertility and Productivity Aspects

K. R. Krishna, PhD

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TORONTO NEW JERSEY

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Apple Academic Press, Inc
3333 Mistwell Crescent
Oakville, ON L6L 0A2
Canada

Version Date: 20130318

International Standard Book Number-13: 978-1-4665-7829-6 (eBook - PDF)

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http://www.taylorandfrancis.com

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K. R. Krishna received his PhD in agriculture from the University of Agricultural Sciences in Bangalore. He has been a cereals scientist in India and a visiting professor and research scholar at the Soil and Water Science Department at the University of Florida, Gainesville, USA. Dr. Krishna is a member of several professional organizations, including the International Society for Precision Agriculture, the American Society of Agronomomy, the Soil Science Society of America, the Ecological Society of America, and the Indian Society of Agronomy.

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List of Abbreviations

AE_N	Agronomic efficiency of fertilizer-N
BMP	Best management practice
CEC	Cation exchange capacity
DGPS	Differential global positioning system
EONR	Economically optimum rates of N
EC	Electrical conductivity
EMI	Electromagnetic induction
FYM	Farmyard manure
GIS	Geographic information system
GPS	Global positioning systems
INM	Integrated nutrient management
LED	Light emitting diode
NIR	Near-infrared
NDVI	Normalized difference vegetative index
NMR	Nuclear magnetic resonance
PF	Precision farming
RVI	Reflectance vegetation index
SAR	State agency recommendation
SSNM	Site-specific nutrient management
SOC	Soil organic carbon
SOM	Soil organic matter
SPAD	Soil plant analysis development
STCR	Soil test crop response
VRT	Variable rate technology
WFM	Whole farm management

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Preface

Precision is an important concept that has induced, guided, and improved many aspects of human endeavor for ages. Historically, precision has been an important factor in agricultural evolution *per se*. Precision in planting dates and matching crops with seasons to derive maximum advantage from soils and precipitation patterns are perhaps the oldest aspects of agriculture. Farmers have been striving to achieve greater accuracy on these aspects of agricultural cropping since the Neolithic period. They continue to do so even today. There is no doubt that through the ages, precision as a concept has been imbibed into almost every technique and practice during crop production. Precision has been a key factor in selection of healthy seeds, seeding technique, fertile locations, types of manures, and moist zones. Precision has sometimes caused quantum changes in cropping pattern and productivity. Precision in matching soil fertility and its variations with crop species or its genotype with yield goals is a key aspect of agriculture in any part of the world. Precision is needed while selecting a crop genotype. The genotype should match the agro-environment, soils, season, grain yield goals, and profitability. Agricultural cropping trends and productivity, in particular, have depended on the extent of precision bestowed on farming procedures. For example, precise crop genotype, accurate supply of nutrients, and irrigation in time and space were major factors in improving crop productivity during first half of the 20th century. Today, precision techniques offer farmers the greatest opportunity to regulate soil nutrient dynamics, protect agro-environment and yet enhance crop productivity.

During recent years, a perceptibly greater degree of precision has been incorporated into almost all farming procedures. Soil fertility and manure supply trends, in particular, have received greater attention with regard to the extent of precision possible. The advent of computer models, simulations, and decision support systems have allowed us to direct exact quantities of seeds, fertilizers, water, and pesticides through the use of variable-rate technology. Actually, equipments such as computers, handheld sensors, and satellite-guided systems have remarkably enhanced precision during farming. Precision technique creates uniform soil fertility across a field. Grain/fruit and forage productivity too become uniform commensurately. Precision techniques often envisage use of slightly or markedly lower quantities of fertilizers and irrigation to achieve same levels of crop productivity. The reduction in fertilizer usage delays or totally avoids deterioration of soils, ground water, aquifers, and general agro-environment. Precision techniques also provide higher profits to farmers. Overall, reduction in use of natural resources, improved grain/forage yield, and extra profitability compared to farmer's traditional procedures hold the key to its rapid acceptance in most agricultural regions of the world.

During past decade, rapid improvements have occurred in precision techniques. Improvization of GPS-guided farm machinery, sensors, data capture, soil fertility mapping procedures, and GPS-guided variable-rate techniques have been marked.

The spread of precision techniques into different agricultural belts and evaluation of its advantages have received the greatest attention. Precision technique is most recent among the agronomic procedures exposed to farmers/researchers. Field evaluations across different continents suggest it could be a very popular and profitable technology in the near future.

This book, titled *Precision Farming*, is introductory. It begins with a discussion on historical aspects, provides brief descriptions on techniques, and enlists advantages as well as constraints that influence the adoption and spread of precision farming in different continents. Chapter 2 provides details on intricate instrumentation, their functioning, and advantages that accrue during precision farming. Chapter 3 forms the centerpiece of this book. It deals with the influence of precision farming approaches on soil fertility, nutrient dynamics, and productivity of various crops. The spread of precision farming methods into different geographic regions and profitability are discussed in detail in Chapter 4. A brief discussion about the future course of precision farming approaches appears in the last chapter.

This book on precision techniques is concise and provides valuable information on instrumentation and methodology. It encompasses lucid discussions about the impact of precision techniques on soil fertility, nutrient dynamics, and crop productivity. It is most useful to students, researchers, and professors involved in various aspects of agriculture.

— K. R. Krishna, PhD

Acknowledgments

Dr. Eric Lund and others of Veris Technologies, Salina, Kansas, USA, provided pictures of sensors that estimate soil pH, electrical conductivity, and nutrients. Pictures on precision techniques such as management strips, strip tillage, variable-rate supply of fertilizer and seeds, GPS-guided seeder, fertilizer mixing trucks, and fertilizer application systems were obtained from Mr. David Nelson, Nelson Farms Inc, Fort Dodge, Iowa, USA. Pictures of hand-held portable instruments that estimate photosynthetic activity were obtained from Mr. Micheal Larman, CID-BIO Science, Camas, Washington, USA. Pictures of hand-held sensors that measure Leaf-N and chlorophyll content, help in gauging N status of a crop, and in forecasting yield were derived from Konica-Minolta Sensing Inc, New Jersey, USA.

I wish to thank my wife Dr. Uma Krishna and son Mr. Sharath Kowligi.

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1 Introduction

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1.1 HISTORICAL ASPECTS

Precision means exactness or accuracy in performance of a particular task. In the present context, it refers to accuracy of various agricultural practices and farming per square that are carried out by farmers. Precision is actually a concept that got imbibed into agricultural endeavor of human beings, since pre-historic times. Precision also induced evolution of agricultural techniques and farming. Earliest of the steps towards precision could be seen in preferential seeding of a particular crop species in the vicinity of prehistoric human dwelling sites of early to late Neolithic period. Neolithic farmers gained by seeding and growing a precise crop species in those backyards of their dwellings. It overcame difficulty in tedious collection of grains from swamps or plains that had admixtures of all kinds of plant species. In this case, precision in terms of crop species and domestication allowed farmer greater quantity of harvests. It is interesting to note that since these early stages of agricultural history, precision as a concept has been quietly imbibed and utilized too, mainly to make farming easier and enhance productivity of land. Farmers devised procedures and manufactured implements that enhanced accuracy. Precise soil management using plough meant better nutrient and water management. Farmers introduced ploughing and line sowing during ancient period. Ploughing and line sowing is indeed a conspicuous effort to add greater degree of precision into farming, in terms of planting geometry and density, efficient interception of light, as well as moisture and nutrient scavenging. It is a major event in the agricultural history that added precision to farms worldwide. Line sowing improved crop production compared to a field randomly broadcasted with seeds. Tillage and line sowing added precision to several other procedures like timing of interculture operations, top dressing, irrigation, pesticide application, and harvesting. During modern era (1820th century), precision got imbibed into agriculture through various improvements that farmers effected on to their implements, seeding procedures, irrigation devises, harvesting, and grain processing. During this period of history, farmers literally gained in efficiency and productivity by adding precision to farming procedures. Most glaring of the procedures introduced by farmers that added precision are precise planting dates to match with precipitation pattern and season. Even today, we strive hard to add precision into planting dates, seeding depth and plant population because it improves nutrient scavenging, moisture absorption and grain harvests significantly. Precise crop species and precise field to match fertility requirements of crops are other measures that improved productivity. Irrigation channels helped farmers in the supply of precise quantities of water at various stages of the crop development. During recent decades, there has been a steady improvement in precision aspects of implements, gadgets and procedures adopted in the field. Invention of fertilizer formulations improved accuracy further. Soil fertility could be mended accurately and sustained despite repeated cropping of the same field. Soil nutrients could be accurately replenished using various soil chemical analysis procedures and soil test crop response (STCR) studies. Automatic irrigation based on periodic soil moisture measurements and crops' need improved accuracy of crop production. Together, aspects like precise crop species/genotype, nutrient replenishment and irrigation were instrumental in enhancing crop yield. We should note that precise selection and genetic improvement of crop species has added to grain harvests significantly.

Historically, selection of genotypes that flowered and matured uniformly, produced non-dehiscent panicles/seeds of uniform traits have added to accuracy. Production of genotypes with uniform height and panicle development (semi-dwarfs) that aided efficient mechanical harvest is a glaring example that depicts gain in precision through crop breeding. Since mid 1900s, precision as a concept was imbibed as a matter of routine into almost all aspects of farming. Throughout past decades, almost every modification in traction machinery, types of coulters, their shape, size, seed drills, fertilizer drills, hoes, weeders, harvesters, right up to development of elaborate combine harvesters have all aimed at enhancing accuracy of specific tasks. Gadgets driven mechanically or through electrical power added further to precision of agricultural techniques. Electronic controls and timing too added precision to various farm operations.

Historically, most recent of the farming measures that seems to add precision into farming procedures, yet again and in significant amount, is the use of satellite-guided seeding, fertilizer application, irrigation, pesticide spray, harvesting, and yield monitoring. Satellite-guided procedures and computer-aided decision support systems are forecasted to revolutionize the way agricultural farms are managed. Such procedures are collectively termed Precision Farming (PF) because they add accuracy to soil fertility and moisture management, rather enormously. In summary, precision is a concept that has been imbibed into farming. It has helped farmers to carry out various tasks efficiently with due gains in input efficiency and grain/forage harvests. Right now, we have no idea regarding limit to precision or accuracy in farming procedures and the extent of benefits it may fetch. We ought to appreciate that evolution of agricultural operations and gain in precision has affected nutrient dynamics and productivity of the land, either directly or inadvertently. This aspect should be needs to understand in greater detail.

The PF as we know today currently involves, remote sensing, Global Positioning Systems (GPS) guided instrumentation, fertilizer supply based on Geographic Information System (GIS), computer models, and variable rate nutrient applicators. Historically, this aspect of farming is only one and a half decade old. Its development, refinement in technology, introduction and rapid spread into different cropping zones has occurred since mid 1990s. It is relatively a new scientific aspect with a short stretch of history. Some of the earliest references to within field variability pertaining to soil moisture, nutrients, and pH were made as early as 1986. Actually, precision agriculture as a concept that overcomes within field variability in soil fertility and one that provides better synchronization between nutrient need and supply was envisaged in 1986 (Fairchild, 1994). It received greater attention as a method that has impact on resource use efficiency, crop production, profitability, and environment during 1990s (Earl et al., 1996; Gerhards et al., 1996; Khakural et al., 1996).

Farmers situated in most regions of the world, including highly intensive crop production zones like Corn Belt of USA or Wheat expanses in Europe or rice cultivation areas in Southeast Asia or subsistence farming zones in semi-arid regions were ordinarily accustomed to simple and traditional techniques to estimate soil fertility. Then, they prescribed fertilizers/organic manure and recorded harvest derived from entire field. Identification of within field variations regarding soil physico-chemical properties, fertility trends and obtaining productivity maps was not practiced routinely. According to Berry et al. (2010), soil or yield maps played insignificant roles in crop production until mid 1990s. Soil and topographical maps were more generalized and directed towards demarcation of soil fertility regimes. Agricultural crop production was based mostly on whole field estimates of soil fertility. In fact, only broad averages were considered while taking nutrient management decisions. Soil sampling was superficial and done to know physico-chemical conditions and nutrient status at a broad field level. Grain elevators and combine harvesters recorded only final yield per field/farm allowing us to compute only average grain yield per hectare. Such data were used as efficiently and authentically to decide about cropping systems, soil fertility measures, planting densities, irrigation, and disease/pest control measures and harvest schedules. It is interesting to note that during past 15 years, geospatial technology as applied to agricultural crop production has improved enormously. This technology has expanded rapidly from a mere practice to operational reality in several million