4RS AS AN ENTRY POINT FOR PRECISION AGRICULTURE IN SMALLHOLDER FARMING SYSTEMS OF AFRICA
#9618

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ABSTRACT

The implementation of precision agriculture (PA) in Africa at scale may be thought to be more of challenge compared to other areas of the world due to the complexity of its smallholder landscape. However, experiences gained from practical application of the principles of 4R Nutrient Stewardship provide one roadmap to establishing transferable, field-scale nutrient management interventions well aligned with PA's goal of optimal crop productivity and profitability across a variable landscape.

Keywords: 4R Nutrient Stewardship, Nutrient Management

A major aim of precision agriculture (PA) is to observe, measure and respond to between and within field variability in crop growth and yield. Through this, PA seeks to ensure optimal distribution of inputs such as fertilizers based on the documented variability, resulting in increased input efficiency, and reduced variability in crop growth and yield. Crop production in Africa is primarily carried out in smallholder farming systems that are often characterized by low and highly variable yields at various spatial and temporal scales. At lower spatial scales, strong variability in yields at low and optimum nutrient application rates has been documented both between and within farms (Kihara et al., 2016; Vanlauwe et al., 2006), presenting a scope for the use of PA to manage variability and enhance crop productivity in smallholder farming systems of Africa. However, while PA has found success in farming systems generally characterized by large land holdings, monocropping, and highly mechanized systems, smallholder farming systems in Africa are frequently characterized by highly fragmented small land holdings with diverse cropping systems and minimal mechanization. Such conditions pose a challenge to the implementation of PA in Africa based on the tools and techniques that have largely underpinned the success of PA in farming systems such as those of North America, where the use of sensors mounted on farm machinery such as tractors, or on unmanned aerial vehicles (UAVs) is a common practice in observing, measuring, and responding to farm level variability.

In the absence of tools and techniques primarily used to assess, quantify, and account for variability in crop yields in PA, locally relevant proxies that have been shown to sufficiently capture the observed variability within and between fields can be used as a means of accounting for variability in yields in smallholder farming systems of Africa. For instance, at local scales, variability between and within farms is mainly driven by management (Njoroge et al., 2019; Vanlauwe et al., 2006). For example, higher fertility fields that respond strongly to fertilizer applications have associated with prior regular applications of organic resources (Njoroge et al., 2019; Vanlauwe et al., 2006; Zingore et al., 2007).

4R Nutrient Stewardship (Fig. 1) is an approach developed to communicate the right ways to manage applied nutrients based on four principles namely: applying the Right Source of nutrients, at the Right Rate, at the Right Time in the growing season, and in the Right Place. 4R Nutrient Stewardship therefore provides a basis for effective use of nutrients which is important for developing sustainable cropping systems that support improved food production, increased incomes for farmers, and enhancement and maintenance of soil fertility.

The application of 4R principles offers an opportunity for the adoption of locally practical applications that can help mainstream specific objectives of PA (Table 1), once locally relevant proxies have been used to identify and quantify variability at local scales. For example, by providing for the adjustment of local recommendations on fertilizer application rates based on observed variability between or within fields using locally relevant proxies, the 4R principle on Right Rate supports the variable rate recommendation in PA, and ensures the optimal distribution of inputs based on documented variability as envisioned by PA. Similarly, through practical applications that aim at ensuring nutrients are applied at the Right Time in line with crop nutrient uptake requirements, and those that aim at ensuring nutrients are applied where plants can easily access them based on differences in root architecture as provided for by the principle on Right Place, 4Rs related applications ensure the optimization of available nutrient sources in line with the goals of PA.

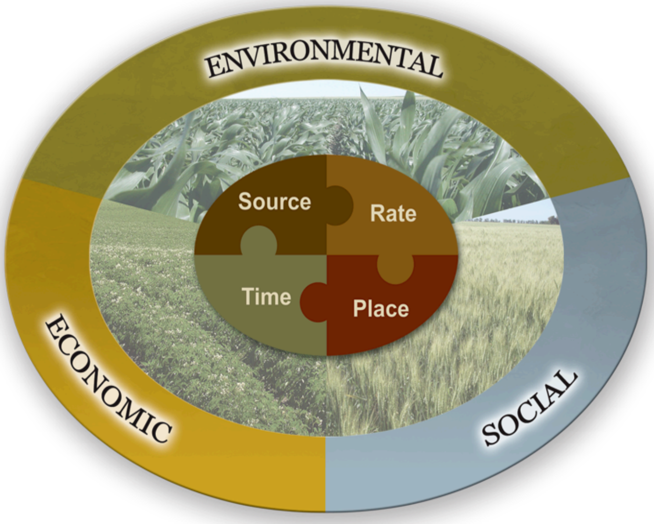

Fig. 1. The 4R Nutrient Stewardship concept.

The ability to implement 4R principles using simple locally available tools such as bottle tops and planting strings that support precise and uniform nutrient applications and guide precise planting respectively, presents an opportunity to override challenges such as limited mechanization and small fragmented farm holdings that limit the implementation of PA in smallholder farming systems of Africa. In addition, implementation of 4Rs alongside improved agronomic practices also helps to deliver multiple sustainability outcomes such as: increased crop productivity, improved profitability for farmers, enhanced nutrient use efficiency, reduced losses to the environment, and improvements in soil health. These outcomes are well in line with the outcomes that result from the implementation of PA, further demonstrating the scope for applying 4Rs as an effective entry point for PA in smallholder farming systems of Africa.

Table 1. Practical applications based on 4Rs that align with key objectives of precision agriculture (PA).

4R Principle	Aim	Practical applications	Link with PA
Right Source	Applying the correct fertilizer and organic resources that provide growing crops with all nutrients required for good growth and maturity.	Ensure balanced supply of nutrients based on e.g. - Plant requirements - Deficient nutrients	Provides basis for optimizing available nutrient sources.
Right Rate	Supplying growing plants with the right amount of nutrients for healthy growth and development.	Adjust rates for differences in field quality based on key proxies.	Supports variable rate applications that account for spatial variability.
Right Time	Matching nutrient application with the timing of plant nutrient uptake.	Match nutrient applications to key crop growth stages.	Ensures optimal uptake of applied nutrients through synchrony with peak nutrient uptake time.
Right Place	Adding nutrients to the soil at a place where the crops can easily access them.	Match nutrient applications to root architecture, tillage system, spatial variability.	Supports optimal distribution of required nutrients.

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