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# Fuzzy decision support system for improving the crop productivity and efficient use of fertilizers

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ABSTRACT

This work investigates the process of reducing the fertilizer consumption and improving the crop productivity using the fuzzy logic systems. The system comprises two parts; land report based expert knowledge to stimulate the yield potential through appropriate organic lacking minerals in soil. The system structure consists of 8 parallel systems. The integrated knowledge and formation of fuzzy rules were based on multiple domain cores professionals – water, soil and agronomy with expert farmer interviews. This research work is to improve the productivity with minimum consumption of fertilizer. The study has been carried out to access the fertilizer consumption in both the ACZ(Agro Climatic Zone) with an exhaustive daily filed measurements and lab analysis for a duration of three years to determine exact fertilizer need for every individual lands. The above data was analysed in MATLAB to establish feasibility rules for decision support systems for the crops to get the targeted output.

## 1. Introduction

Farming, for the most part being a mantle passed down from generation to generation, farmers feel obliged to stick to age old patterns of farming right from the seasons of working the ground to ritualistic harvest practices. Only recently in the past decade have farmers started adopting informed crop cycle patterns (Soleri and Cleveland (2004). In general, farmers have an opinion that more fertilizer equals more yields yet it cannot be farther from the truth.

The role of chemical fertilizers is very important and acceptable, because it plays an important role in increasing soil fertility and increasing crop production (Jallah et al., 1991; Simonne et al., 2017). However, long term usage of inappropriate chemical fertilizers will decrease the quality of soil and increase the soil degradation and effects ecological pollution (Ayoub, 1999; Patnaik, 2010). Sometimes the fertility and quality of the soil is heavily affected due to the knowledge void of the farming community. The impact of the chemicals is the most severe among the various others. Savci (2012) and Ning et al. (2016) have mentioned the vulnerabilities of chemical fertilizers and the contamination of various types of environmental pollutions. Aziz et al. (2015) have reported in detail about the need of fertilizers and their impacts on environment. On this basis, we have come to know the effects of chemical agriculture and the adverse effects it has on our agricultural lands. So every attempt at remediating the damage done is being attempted by mindful and discerning farmers/agricultural engineers. But the efforts to shift from modern agricultural practices to primitive yet more effective methods of cultivation presents its own set of complications, as our lands have lost the bounce back ability to cope up with organic and natural cultivation methods to produce a similar quantum of agricultural produce upon termination of chemical inputs. Fertilizer usage and crop production are heavily interlinked processes, especially in horticultural crops (Fageria, 2001). Soil and Water quality, fertilizer quality and quantity, micro nutrients, and climatic factors, are all equally important, and if even one of them is not optimum, then the production is affected (Lal and Moldenhauer, 1987).

Several models have been proposed by many researchers for the issue of fertilizer consumption considered through various points of view. Zhang et al. (2016) using the platform of Network of Science and Technology Backyards (STB), have examined fertilizer consumptions during the span of crop cultivation. As per their findings, the yield of wheat increased by 11% with addition of 1.5% Nitrogen alone. Nájera et al. (2015) evaluated soil fertility from soil samples of 31 maize cultivating farmers by testing micronutrient and macronutrients. They found that the Maize does fairly well in neutral- alkaline soils along with high inputs of NPK and Zn. Delzeit et al. (2017) presented a concept of trade-off between crop production and crop diversity, along

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with crop land expansion for improving food security, in the context of possible food shortage scenario in the decades to come (Natarajan et al., 2016) have analysed sugarcane yields in Coimbatore, Tamil Nadu and have suggested optimum parameters for both soil nutrients as well as environmental factors for cultivating sugarcane. Toyonaga et al. (2005) addressed the problem of crops chosen seasonally in Japan. Apart from their formulated problem, they also introduced the concept of fuzzy based profit coefficients for a more efficient and effective farming model. Fan et al. (2011) concentrates on the use of minimum amount of fertilizer to get efficient outcome with respect to environmental pollution in China. Papadopoulos et al. (2011) analysed the nitrogen fertilization requirement for cotton through a fuzzy based decision support system, which analysed 30 years of rainfall data and 8 years of temperature data. Šeremešić et al. (2013) had conducted a long term experiment of 20 years, analyzing climatic data such as temperature and rainfall for their effects on the yields of maize using fuzzy logic. Ashraf et al. (2014) had designed a decision support system for wheat crops, with fuzzy systems, which deals with fertilization by primary (NPK) nutrients alone. Yengoh and Ardö (2014), using fuzzy logic sets, analysed the food security provided by bolstering the production of two different food crops, by the method of fuzzy linear regression. Habib et al. (2017) implemented fuzzy logic, based on climatic parameters, oriented towards tomato cultivation for the entire South Asian Agro Zone. They developed and introduced three climate control systems for their study which uses the concept of Adaptive neuro-fuzzy inference system (ANFIS). Sivakami and Karthikeyan (2009) has designed and evaluated a Decision Support System for maize using Visual Studio 6 Programming Language.

Ogunkunle and Beckett (1988) and Malley et al. (2004) emphasizes that soil analysis process does not directly improve performance, but it maintains soil fertility and maintains the crop growth rate as it is a walkway platform between soil nutrient and soil fertility. Rajput et al. (2016) and Wani et al. (2017) reported that the crops are grown with long term soil analysis process has resulted in increased soil performance, soil organic carbon, soil nutrient and soil micro organisms which eventually culminates into increased benefit cost ratio by reducing the pollution and indirect cost.

The aim of the proposed system design is to improve the productivity and its quality with less fertilizer utilization which is carried out in several stages. The first step would be identifying the condition of the field and constant monitoring of its fertility using periodical standard soil and water analysis tests. It would be followed by planning the crop cycle for the entire period of the study along with the fertigation planning and finally the growth phase of the crop where in the farmers would be kept informed about the condition of the soil and remedial measures, if necessary in case of impending crop failure. Soil inputs, if they are in excess, deteriorate soil quality (Wallace, 1994). Therefore the soil was examined and the nutrient balance sheets were obtained which is crop specific. Based on the soil analysis test report from the experts, it depends on the nutrient prerequisite for a particular crop. As an illustration for *Allium cepa*, the nutrient balance sheet shows the nutrient available in the soil (Table 2). Nutrient balance sheet is a valuation of nutrient in the soil and provides valuable information such as its losses, pattern of fertilizer used in agricultural practices and the rule of applied nutrition to farming systems (Eulenstein et al., 2014). The method tested in this study warrants against these failures while ensuring the levels of inputs stay at the required minimums, which in turn also reduces production costs, with the consequent increase in Benefit Cost Ratio (BCR). The method also provides a way of returning back to sustainable agriculture in calculated increments by reduction of soil inputs, allowing for recovery period of the soil and by finally sensitizing the soil to organic inputs by cutting out excess chemical fertilizers. The method utilizes the concept of fuzzy logic to evaluate the required inputs for the soil and the crop. Fuzzy logic has become the go to technique which is being applied in many research platforms, including Medical, Wireless Sensor Networks, Artificial Intelligence and Engineering Applications; Electrical Energy Consumption, Fog Forecasting (Azadeh et al., 2013; Miao et al., 2012). Previously, fuzzy system has been utilized in the purview of agriculture for managing fertilizer consumptions and in particular to reduce excess usage of primary nutrients like NPK either individually or as a whole and simultaneously use the minimum amount of fertilizer to improve the productivity. By following this process environmental pollution has been reduced to half and emission of $N_2O$ and $CO_2$ compounds has also been reduced (Fan et al., 2011).

This is an attempt to employ fuzzy based system to validate an array of soil, nutrients, water and climatic parameters to arrive at conclusions on best inputs for the particular crop and soil. In agriculture, the role played by land, water and fertilizer cannot be defined individually. However each has a sizeable contribution in association with the rest towards better productivity. There had been attempts by researchers, earlier, with primary, secondary and micronutrients of the soil. But the proposed system, the nutrient concentration along with water and climatic conditions are given cognizance for determining the productivity. The soil data is obtained through periodic soil tests done on each farmer's land. It is evaluated at frequent intervals to monitor changes in soil properties immediately after changes in input patterns. The increased consumption of fertilizers has been due to ignorance in effective crop rotations, wherein farmers have been accustomed to a particular crop cycle throughout their lives and are unable change out of it, and uninformed usage of fertilizers, where most of the farmers believe that more fertilizers gives higher yield. The apparent failure of the farmer to think beyond the field, to the market and be cognizant of the climatic predictions has been another big reason for the dire state of agriculture in the country. Our model takes into account all of these parameters and provides comprehensive suggestions for every individual farmer, backed by the validation of experienced agricultural engineers and farmers in their ACZ (Agro Climatic Zone). During the study period from 2013 to 2015 the results obtained were in line with our expectations. Considering the mentioned literatures, it is seen that previous studies do not go beyond the purview of primary nutrients. Therefore in this proposed system a routine soil analysis process has been carried out for all nutrients including secondary and micro nutrients, and across multiple crops. The system pays cognizance on expert opinion regarding the parameters monitored and tracks the outcome of every suggestion implemented.

## 2. Methods and materials

This section provides the explicit information about the methodology. The study began in 2012–13 and ended in 2015–16 and a study was conducted in two agro climatic zones. For this purpose 80(each 40) farm lands were selected and the study appears in detail in the system implementation section presented as the supplementary material. Crop Cultivation is followed by regular inspection of soil parameters, climatic parameters, water quality and fertilization. The uncertainty involved in the determination of each of the natural factors results in vagueness. Fuzzy system quantifies vagueness into a meaningful parameter for analysis. Therefore, we have created a fuzzy based model. The soil parameters, climate parameters, water quality and fertilization are continuously monitored and thereby increased the productivity using low fertilizer consumption. Crops under study were *Allium cepa*, *Momordica charantia*, *Lagenaria siceraria*, *Musa*, *Trichosanthes cucumerina*, *Citrullus lanatus*, *Cucumis melo*, *Solanum lycopersicum*, *Solanum melongena*, Capsicum frutescens, *Brassica oleracea var. botrytis*, *Oryza sativa* in the two agro climatic zones.

### 2.1. Fertilizer balance

In order to reduce the fertilizer consumption the availability of nutrient concentration in the soil is calculated using the given equation below