

Chapter 5

IMPACT OF SOIL PARAMETERS ON CROP YIELD-A BRIEF REVIEW

The chapter outlines the impact of soil on crop productivity. Different mathematical and statistical tools employed by the researchers were reviewed. The correlation between the different soil parameters were studied. These parameters were assumed to be constant for the model formulated for the study.

5.1 Mathematical Tools-Illustrating the Impact of Soil on Crop Yield

Evaluating the relationship between soil and crop yield is quite complex as it depends significantly on physical and chemical properties of soil and other external parameters. Analyzing the soil composition, properties, and estimating its impact on crop yield is one of the critical issues for practicing sustainable development and land-use planning. Several statistical and mathematical approaches (Boyabathlı et al., 2019; Filippi et al., 2017a; Leemans & Solomon, 1993; Peltonen-Sainio et al., 2019; Reca et al., 2001) have been developed by researchers to predict the crop yield. Due to interactions among various factors impacting the crop yield, assessment of the soil parameters influencing the production is often a complex and challenging issue. Several mathematical and statistical analysis had been employed by the researchers to determine or evaluate these relationships.

The reason behind the existing interrelations and correlation among the soil attributes is the process of soil development (Moore et al., 1993). As a result of existing relationships among the parameters, one of the most common issue encountered while applying regression analysis (Adams et al., 2004; Kbakural et al., 1999; Kravchenko & Bullock, 2000) is to examine the relative importance of the variables that participate/contributes in the soil function. This, issue would overcome by grouping the variables, resulting in high correlation within the same group (Jolliffe, 2002). Factor Analysis (FA) is employed by the researchers to illustrate the significant correlation among the variables.

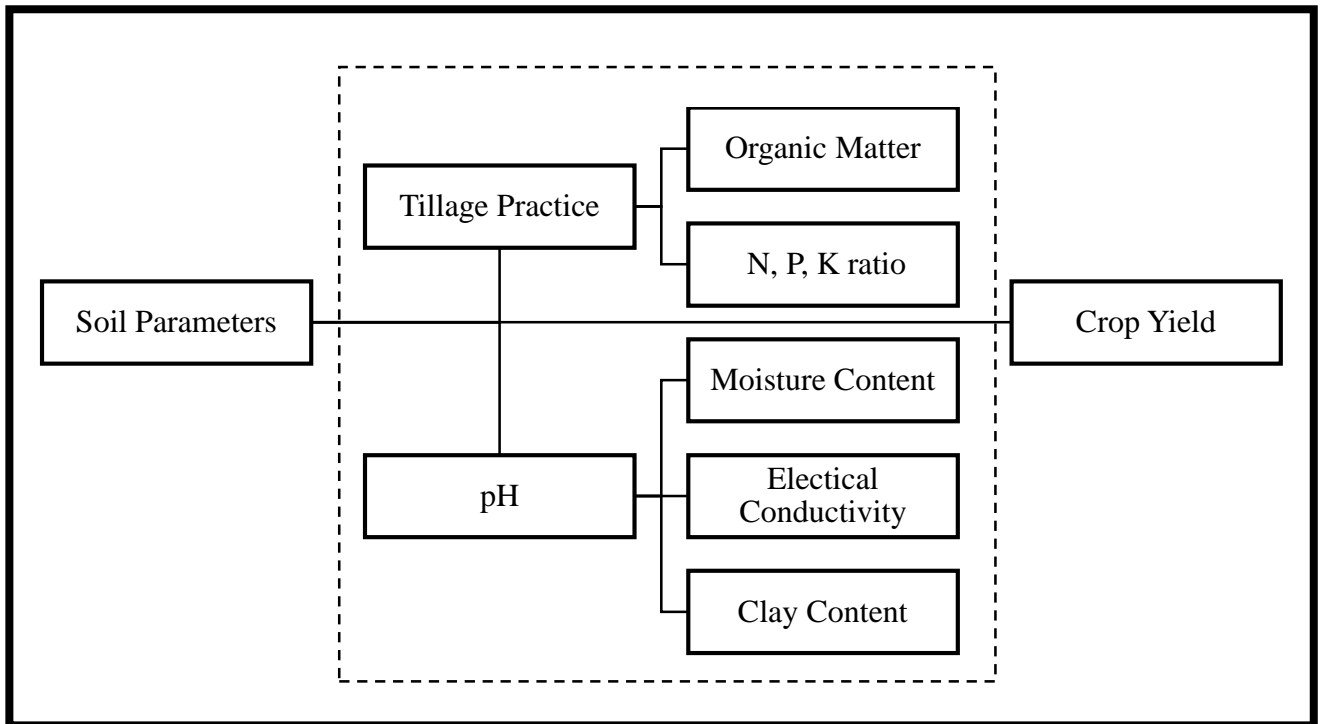


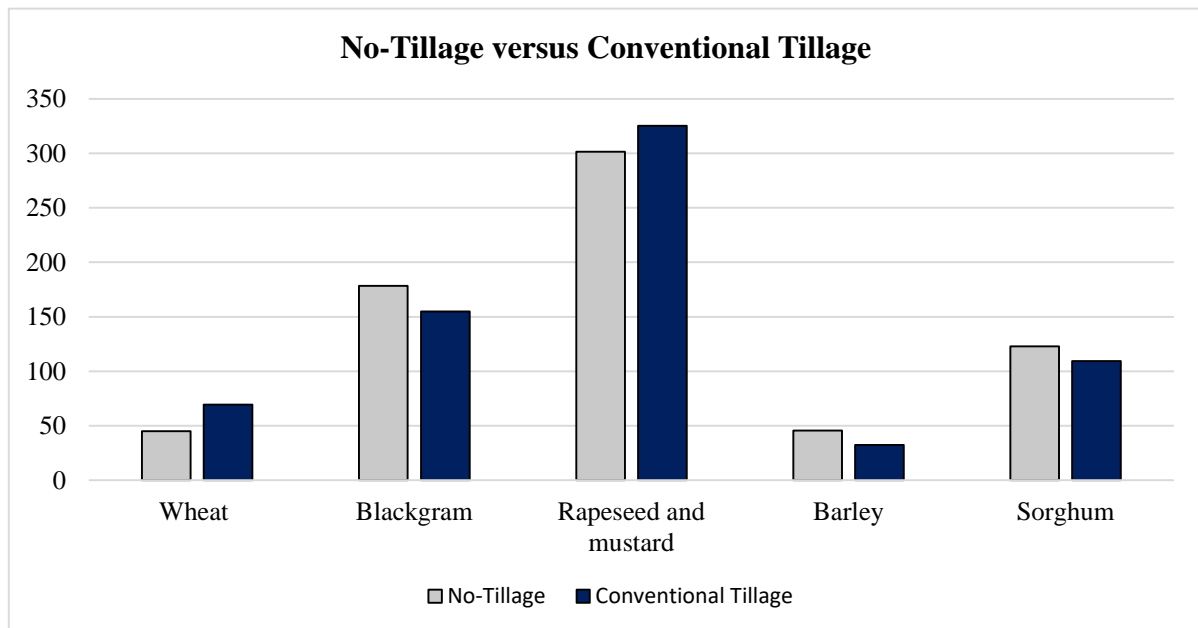
Fig. 5.1: Soil Parameters Impacting Crop Production

In current scenario emphases is laid on sustainability of agricultural systems and practices, to minimize the use of an additional input to improve the quality and to increase the yield. Thus, dependence on soil’s intrinsic capability to maintain a favorable condition for plant growth has gained an attention over a year. Crop yield and its quality depends on variety of seeds and soil fertility. (Persson and Otabbong 1994) defined the soil fertility as the “ability of the soil to produce good yield on the basis of its chemical, physical and biological composition”. (Doran & Parkin, 1994) explains soil fertility as an important aspect of soil quality.

However, identification of soil properties (Fig. 5.1) for defining soil function is a challenging issue. Assessment of soil quality for in-depth analysis of physical, chemical, biological attributes of soil and their variability over space is needed. For estimating the impact of soil attributes on crop yield, the interactions among all these attributes were considered. Soil pH value and organic content are the major components that reflects the soil quality. (Gregorich et al., 1994) defines organic matter as a blend of humified and biologically active compounds including C (carbon) and N (nitrogen) though in less quantity; plays a significant role to improve a soil quality. Since, biological activity is based on complex interactions with physical and chemical components, thus contributes; to be evaluated as one of the soil indicators. Soil with high clay content restore more organic content as compared to that of less clay content (Jenkinson & Powlson, 1976).

To classify the soil as good, normal and poor in context of organic content (Stenberg, 1998) a multivariate analysis and partial least square regression is carried out. Both qualitative and

quantitative measures were considered. There are only few authors that contribute to explain the interactions of biological variables and crop production. (Insam et al., 1991) explains that the variation in crop variability is significantly impacted by level of fertilizer inputs. In addition, tillage is an important agronomic practice for optimal plant growth (Alam & Salahin, 2013). Due to the difference in the amount of N fertilizers in the soil, no tillage increases the soil acidic content. Graph 5.1 illustrates the average net return of some of the crops cultivated in region to determine the impact of tillage practices on crop productivity.



Graph 5.1: Average net return tillage versus non-tillage practices

Source: (Toliver, 2010)

(Gentili et al., 2018) investigates the impact of different pH values on plant growth, vegetative propagation. He illustrates the germination rate (Fig. 5.2) based on different pH values. He explains that the soil pH controls the macronutrients intake by plants. Thus, alkalinity and acidity of soil is crucial in plant growth and productivity.

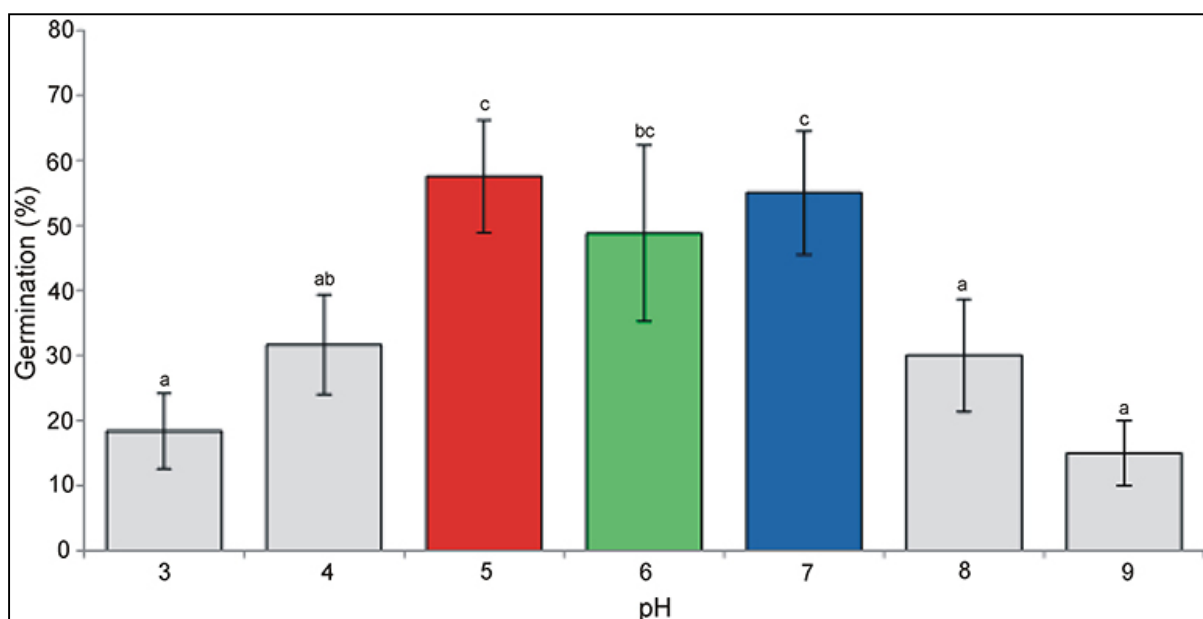


Fig. 5.2: Germination Rate Under Different pH Values

Source: (Gentili et al., 2018)

However, the suitability of these approaches depends on the nature, structure and size of data base. (Andrews & Carroll, 2001; Brubaker et al., 1993; Doran & Parkin, 1996; Rezaei et al., 2006) by applying stepwise linear regression, concluded that the pedological indicators shows a significant relationship with crop yield. However, simple linear regression is not able to describe the appropriate results, reflecting the impact of soil indicators on yield. Intercorrelation among the soil properties results in multicollinearity problems. By grouping the variables, the problem caused by correlated variables can be encountered as this would increase the correlation among the variables of the same group. A new variable created from the group, represented by the variables in each group so formed. Since Factor Analysis is an analysis of covariances thus, the techniques can be successfully employed for identification of groups of the correlated variables. (Mallarino, 1999b) by using factor analysis showed that the analysis is appropriate for identifying the group with correlated variables that were significantly correlated with yield variability.

However, pedological indicators were not able to (Juhos et al., 2015b) explain the relationship between the crop yield and soil properties. Some of the variable that were considered to predict the effect of soil on yield includes: soil pH, CaCO₃, EC (Electrical Conductivity), Al-Na, topography, silt & clay, organic content, Al-P₂O₅, Al-K₂O and Hargitai-N. The study concludes that, to explain the relationship between pedological parameters and crop yield, multivariate

statistical analysis is required. To understand the variance in crop yield it is important to determine the spatial variability of organic carbon and pH (Vieira & Paz Gonzalez, 2003).

(Andrews et al., 2004) developed a Soil Quality assessment tool to investigate the impact of soil parameters on overall soil function. A non-linear mathematical model is proposed to investigate the impact of different tillage practice adopted by growers and intercrop pattern with legume plants were discussed (Dahmardeh & Hodiiani, 2016a) with the aim to increase the soil fertility and efficient use of resources. A non-linear parametric modelling technique is applied by (Whetton et al., 2017) to quantify individual, interaction and overall influence of soil properties on crop yield. On other hand, (Bai et al., 2018) evaluates the impact of no-tillage and crop rotation on soil function. From the reviewed study it can be said that the soil tillage and no-tillage practices adopted, participate actively in crop production function. (Wander & Bollero, 1999) studied that the adaptation of non-tillage practices had improved the soil physical and biological composition.

Science-Based soil quality indices (SQI's) accounts an information to facilitate the information about complex issues such as agroecosystem management (Andrews & Carroll, 2001). Thus, (Harris et al., 1996) argues that choosing an appropriate soil attribute to include in the index must include in soil function. SQI can be considered as one of the measures of sustainability apart from the fact that it will influences the crop yield too. Thus, the soil function is defined by the index and soil attributes (Andrews & Carroll, 2001). The methodology produces interpretable combined variables. However, (Ayoubi et al., 2009) explain the relationship between the soil attributes and yield by using linear multivariate regression analysis.

Some of the researchers use partial least squares regression (Corwin et al., 2003; Ping et al., 2004) to resolve this issue of multicollinearity. The approach identifies the soil properties that greatly influence the crop yields. Based on the linear correlation among the soil components another way to combine the variables is, Principal Component Analysis (PCA). The structure of set of variables is simplified by using PCA as it replaces those with a few uncorrelated linear combinations of original variables. However, PCA factors were not able to explain the total variance in the data set. Some of the mathematical techniques reviewed were listed in Fig. 5.3.

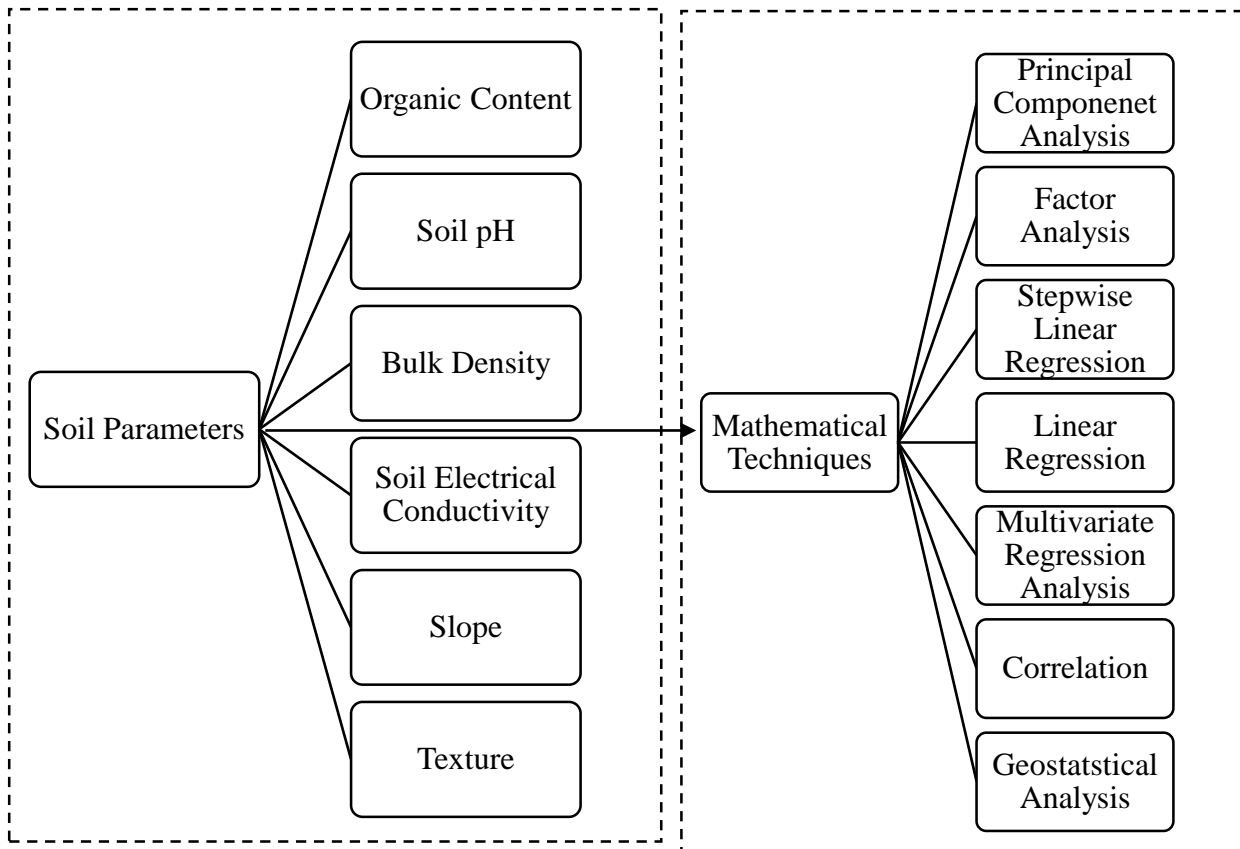


Fig. 5.3: Soil Parameters and Reviewed Mathematical Models

The correlation among the soil variables emphasizes that the relationship between the variables is independent of spatial distribution. Simple correlation techniques show that not all the parameters measured from producers' field were often correlated with the crop yield and in addition some of the variables shows correlation among themselves. If these correlated variables were used in multiple regression analysis to explain the crop yield, the results of regression results will be difficult to interpret. This is because in regression analysis the value of one variable changes, depending on the other variables, defined for analysis.

Moreover, as a result of high correlation among the variables the coefficients of test of significance became unrealistic. Thus, in such situation PCA, multivariate analysis, factor analysis is used to facilitate the analysis. To some extent multivariate analysis resolve this complexity of correlation and interpret the complex relationships.

5.2 Crop Pattern- Improvising Soil Fertility

(Tesfahunegn & Gebru, 2020) verifies that the different cropping pattern adopted to improve the mean yield often influences the soil fertility. Intercropping, adopted by the farmers to

maintain the soil quality, and reduce the risk of crop failure (Dalal, 1974; Harris et al., 1996; Uddin et al., 2018). Several studies have been conducted by researchers to evaluate the impact of tillage (Clapp et al., 2000), fertilization (Yousaf et al., 2017), and crop rotation (Soman et al., 2017) on soil organic content. Thus, practicing different crop pattern (Fig. 5.4) is one of the aspects of sustainable agriculture; proposed by increasing per unit area under cultivation to increase productivity (Bodner et al., 2013).

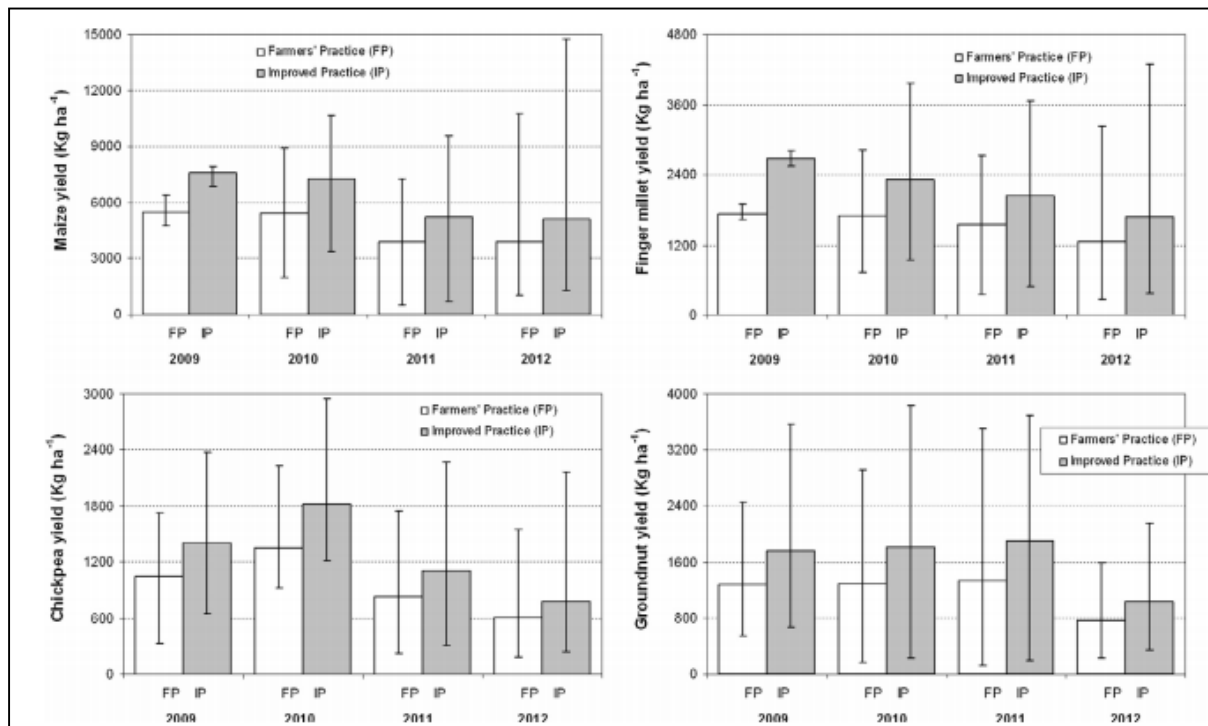


Fig. 5.4: Comparison of Crop Yield Based on Farm Practices

Source: (Wani et al., 2017)

In intercropping, adoption of nitrogen-fixing legumes as an intercrop balances the soil nutrients. (Hauggaard-Nielsen et al., 2003; Monneveux et al., 2005; Schipanski et al., 2010) argues that the intercropping accompanied with legume-cereals as an intercrop improve crop productivity and soil fertility by increasing carbon, nitrogen content. Ghamari Rahim et al. (2011) showed that an intercropping of maize and soyabean has increased soil organic content to about 1%, indicating that cultivating soyabean as a monocrop has increased the organic content whereas maize reduces the carbon content.

(Yousaf et al., 2017) argue that the principal factors determining the farm optimality were; crop nutrient uptake and crop yields. Thus, optimal allocation of fertilizers is an efficient way to reduce the losses and to improve the productivity.

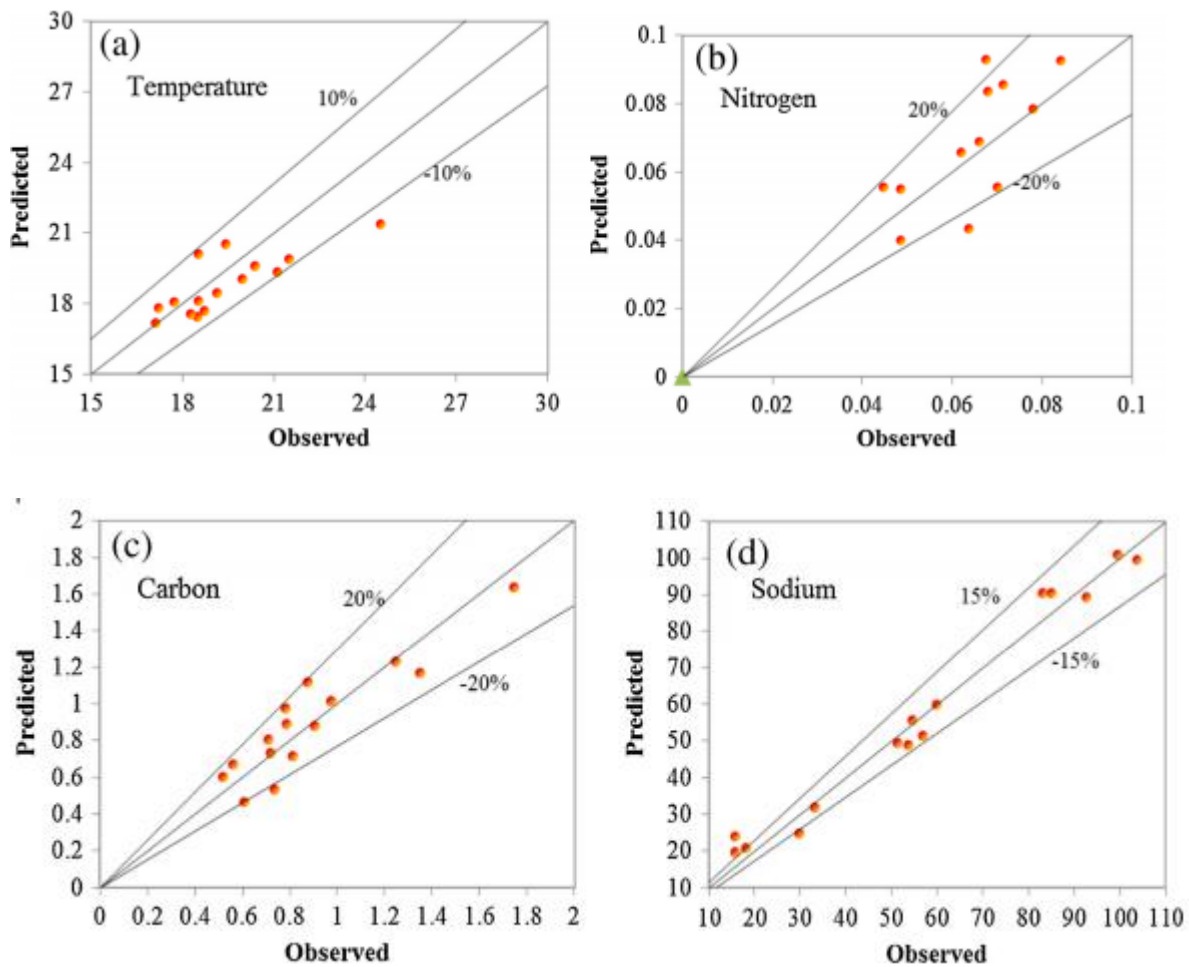


Fig. 5.5: Performance of predicted models (a) temperature model, (b) Nitrogen model, (c), Carbon model, and (d) Sodium model.

Source: (Dahmardeh & Hodiani, 2016b)

(Fig. 5.5) illustrates the models for nitrogen, carbon, sodium and soil temperature. The graphs will help the decision makers to evaluate, the soil properties based on appropriate input variables.

Barley and wheat are the crops cultivated in Rabi season in region with arid and semi-arid topographical features. However, in drier regions barley is preferred over wheat (Wahbi & Sinclair, 2005). The crop adaptation in a region with arid topography, is supported by its resistant to aridity and salinity (Yousfi et al., 2007). Thus, identification and evaluation of the soil properties supports the growers to improve the yield. (Ayoubi et al., 2009) explains the variability in barley grain and biomass yield by using Factor Analysis. (Aman & Bhatti, 2015) compared the regression models to predict the crop yield based on measured soil properties.

There is a need to understand that the continuous practice of same farm operational activities and cropping pattern reduces the soil fertility in addition, making crop sensitive to changing environmental conditions. Geostatistical analysis (Usovicz & Lipiec, 2017) is a useful tool to determine the spatial interrelationships of crop yield and soil properties. These interrelationship supports the policy makers to evaluate the spatial crop distribution over a region.

The variability in mean crop yield is dependent on weather across a region and topographical features as well. Since so many parameters were involved to predict, how the soil factors will impact the crop yield thus, a brief review is carried out to determine these factors. From the reviewed literature it can be concluded that only several researchers explain the relationship between pedological factors and crop yield. Since soil parameters are highly correlated thus, researchers most often use Principal Component Analysis (PCA), Factor Analysis (FA) and multivariate regression analysis to explain the interdependency of the variables on each other. Thus, for evaluation of crop pattern distribution in Rajasthan the soil parameters were assumed to be constant. Table 5.1 presents the district wise soil distribution in Rajasthan.

Table 5.1: Soil Distribution in Rajasthan

Tropical Division	Districts	Soil	Crops	
			Rabi	Kharif
Western Desert	Jaisalmer, Bikaner, Barmer, Jalor, Jodhpur, Ganganagar, Sirohi, Jhunjhunu, Pali and Sikar	Alkaline and saline soils with a calcareous base	Wheat and Mustard	Kharif pulses and Bajra
Irrigated North western plain	Ganganagar	Alluvial and aeolian soil	Sesamum, wheat, mustard, gram, fruits	Maize, guar
Semi - Arid Eastern Plains	Dausa, Tonk, Jaipur and Ajmer	-	Barley, gram, wheat, mustard	-
Flood Prone Eastern Plains	Bharatpur, Alwar and Dhaulpur and the northern region of Sawai Madhopur	Alluvial, clay and loamy soil	-	-

Aravalli Hills & Sub-humid Southern Plains	Bhilwara district and the major parts of Udaipur district, Chittaurgarh district, Sirohi district and the tract of Aravalli Hills	Dark- lava soil	Cotton and sugarcane	-
Humid South- Eastern Plains	Baran, Bundi, Jhalawar and Kota	Black soil	Cotton, sugarcane and opium	-
	Dungarpur, Banswara, Udaipur, Bhilwara and Chittaurgarh have	Red and yellowish soils.	-	-