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Review Article

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Cropping Systems through Optical Sensor Monitoring and Soil Moisture Measurement in Maize-Bean Crops

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Abstract

Maize-legume cropping systems are practiced under conventional crop production (CP) which has resulted in soil degradation and frequent crop failure, which may be slowed or reversed with conservation agriculture (CA). Traditional plant tissue sampling and analysis is time taking and destructive method; whereas optical sensor techniques in particular, normalized difference vegetative index (NDVI) are an instantaneous, non-destructive, and quantitative assessment. CA can improve soil health and crop productivity. However, CA has not been well studied considering different crop and soil parameters for its impact on soil and maize productivity in Ethiopia. Additional to increased crop productivity, sustainable intensification technologies need to demonstrate improved input use efficiencies, and minimal environmental impacts through the conservation of resources and maintenance of soil productivity. Developing soil management practices, which store and conserve as much rainwater as possible by reducing runoff and improving infiltration opportunity time and increase the water storage capacity of the soil profile is essential in the sem-arid of Ethiopia. This review concludes that zero tillage with residue retention results in better water infiltration and soil fertility throughout the plot, avoiding soil degradation as well as reducing plant competition and as such spatial variability.

Keywords: Conservation agriculture; Normalized difference vegetative indexl soil moisture

Introduction

Maize *(Zea mays L)* and common bean *(Phaseoulus vulgaris L.)* are planted by small scale and commercial farmers in monocropping, intercropping or rotation cropping system as a strategy for improving food security. Maize and common bean are important crops in Ethiopia and are mostly grown by resource-poor farmers in risky farming systems. Maize is the second most important main staple and common bean is an important dietary protein source for the rural poor smallholder farmers in Ethiopia. The two crops are mutual to each other when used in rotation and intercropping systems, but these cropping systems are practiced under conventional crop production (CP) which has resulted in soil degradation and frequent crop failure especially in the semiarid regions. The CP practice which involved cereal monoculture with repeated tillage and without crop residue retention has contributed to soil degradation and poor harvests in the semiarid Central Rift Valley of Ethiopia (Liben et al., 2017) [1].

Smallholder farmers in Ethiopia practice crop rotation only after crop yield reduction is observed due to soil degradation or crop disease build up in the field. Maize intercropping with an early maturing legume is practiced to reduce the risk of total crop loss in the semiarid agro ecologies in cases of high probability of soil water deficits occurring during early reproductive stages of maize. Liben et al. (2017) showed importance of improved maize and common bean-based cropping systems practices to reverse negative effects of soil degradation and rainfall variability on maize and legume production in the semiarid Central Rift Valley of Ethiopia. It is becoming increasingly recognized that agriculture is an important cause of environmental degradation. The solution recommended is to manage the resources so that they are neither degraded nor depleted and ensure a sustained production for future generations [2].

Agricultural production systems which improve soil fertility and yield through conserving resources, environmentally non-degrading, technically appropriate, and economically and socially acceptable was suggested for regions with poor soil and erratic rainfall (FAO, 2008). Conservation agriculture (CA) is a set of cropping principles aiming at sustaining high crop yields with minimum negative consequences on environment-reduces crop production processes that contribute to emission of greenhouse gases, soil degradation and water pollution (Baudron et al., 2011). The negative effects of soil degradation and climate variability may be slowed or reversed with CA, which includes no or minimum tillage, retention of crop residues, and crop rotation or intercropping systems (Sherrod et al., 2003; Liben et al., 2017, 2018). Practice of CA may reduce such risks through water conservation [3]. However, results from comparisons of CA with CP have been inconsistent and require more localized evaluation and adaptation (Liben et al., 2017, 2018).

According to Govaerts et al. (2007a) CA has many advantages over CP which included soil moisture retention which allows earlier planting for longer maturity varieties, reduced runoff and evaporation, reduced erosion, soil water conservation, and less labor and draft power demand, and improved crop yields. CA improves soil properties such as increased soil organic C, reduced soil compaction with reduced penetration resistance and bulk density, higher rates of water infiltration and increased time-to-pond. Crop growth and development as well as yield are the integrated evaluators that show the efficiency of the chosen agricultural management system within the boundaries of the agro-ecological environment (Verhulst et al., 2011) [4].

Optical crop sensors have the potential to be used as a monitoring tool for scheduling nutrient applications and in-season crop

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performance assessments. Traditional plant tissue sampling and analysis is time taking, labour intensive and requires collection of several samples from representative areas to adequately characterize variability found on crop field. This is time taken and destructive method which results unnecessary applications of fertilizer N and result in nutrient runoff and leaching with ultimate contamination of surface and groundwater [5].The Green seeker™ handheld normalized difference vegetative index (NDVI) sensor (Ntech Industries USA) was tested as a tool to measure within plot spatial variability and maize crop management (Govaerts et al., 2007a; Liben et al., 2018). The ability to accurately predict yield of field crops such as maize allows producers, economic agencies, and buyers to make decisions with respect to crop management, pricing and available markets. Optical crop sensor techniques in particular, NDVI are used to estimate yield by providing an instantaneous, non-destructive, and quantitative assessment of the crop's ability to intercept radiation stages photosynthesize (Ma et al., 1996) [6].

Development of optical sensors that can reliably identify nutrient deficiencies may reduce time spent and allow for site-specific applications of fertilizers. The NDVI is successful in predicting photosynthetic activity, because this vegetation index includes both near infrared and red light. Plant photosynthetic activity is determined by chlorophyll content and activity. The relationship between leaf N and leaf chlorophyll has been demonstrated for maize (Chapman, 1997) and wheat (Evans, 1989). Therefore, spectral reflectance data can be used to compute a variety of vegetative indices which are well correlated with agronomic and biophysical plant parameters related to photosynthetic activity and plant productivity (Adamsen et al., 1999; Ma et al., 2001) [7].

Recent advances in precision agriculture technology have led to the development of ground-based optical sensors (or crop canopy sensors) that calculate NDVI readings. Active sensors have their own source of light energy and allow for the determination of NDVI at specific times and locations throughout the growing season without the need for ambient illumination or flight concerns. Crop canopy sensors are relatively small in size and contain an integrated light source. They operate by directing visible light (VIS) (400–700 nm) as well as near infrared (NIR) (700–1300 nm) light at the plant canopy of interest (Campbell, 2002). Both water and N stresses altered reflectance and lowered normalized difference vegetative index (NDVI) values. It suggests that it may be possible to use spatial and temporal patterns of plant reflectance spectral index for in-season water and N management (Plant et al., 2000) [8]. As plants become stressed, they exhibit decreased reflectance in the near-infrared (NIR) spectral region due to decreased cell layers and increased reflectance in the red spectral region due to decreased chlorophyll content (Guyot, 1990). Monitoring this change in spectral reflectance may reliably indicate changes in plant growth or physiological status and can be used to evaluate cropping system performance under different tillage systems (Carter, 1994) [9].

The NDVI has been used in many different ways, including estimation of crop yields and end-of-season aboveground dry biomass. Soil texture, moisture, plant cover, and landscape surface roughness could affect soil and plant reflectance the visible and NIR wavelength regions (Asner, 1998). As water and N availability are recognized as limiting factors for maize production in the semi-arid of Ethiopia, optical sensor data could be the basis for water, N, and crop management. Stress events, such as drought, reduced spectral estimates of absorbed radiation and NDVI in corn and soybean canopies (Daughtry et al., 1992). Ethiopian farmers follow traditional fertilization practices which is based upon wide regional recommendations which fail to account for the intra-field variability and temporal variability of the crop nutrient requirement. This problem can be addressed with the help of NDVI which is a precision agriculture tool. Yield prediction models based on early growth stage parameters are one desired goal to enable precision farming approaches to improve production [10].

Understanding the relationship among crop reflectance, water and N inputs, and field heterogeneity would be useful for further evaluation of Optical sensor as a tool for moisture and fertilization monitoring. But there are only few studies that assessed the role of NDVI index to measure impact of crop management practices on crop growth and yield in Ethiopia. Yields can be measured as an end of season static result of seasonal crop performance, but these results do not reflect the fluctuations of the crop's performance throughout the season.

To understand and evaluate cropping systems, and to fine-tune resource management, insight in crop performance over time is crucial [11].

Conservation and conventional agriculture

Infertile soils, unreliable rainfall and inadequate management of the natural resource base have led to declining yields and increased risk of crop failure in much of the smallholder dry land farming of Africa. Tillage in the predominantly maize-based cropping systems on small farms in the region is typically manual using a hand hoe or a single-furrow, animal drawn mold board plough. The plough was introduced from Europe in the early 20th century, but the negative effects were soon apparent and contour bunds were enforced on sloping lands to control soil erosion and runoff (Alvord, 1936). Tillage-based conventional agriculture is assumed to have led to soil organic matter decline, water runoff and soil erosion (Derpschet et al., 1991), and other manifestations of physical, chemical and biological soil degradation (Benites, 2008; Kerte´sz et al., 2008) [12].

Frequently occurring seasonal droughts, nutrient mining and overgrazing add to the crop production risks for smallholder farmers in Africa. As a consequence, there is high pressure on the livelihoods and food security of Africa's most vulnerable (CIMMYT, 2004). Land degradation and associated soil fertility depletion are considered the major biophysical root causes of the declining food production and natural resource conservation in sub-Saharan Africa (Vanlawe et al., 2010). Crop management systems involving a combination of sustainable production practices has the major attributes on improving soil properties and yield. It is stated that negative effects of soil degradation and climate variability may be slowed or reversed with CA, which includes no or minimum tillage, retention of crop residues, and crop rotation or intercropping systems (Sayre, 1998; Sherrod et al., 2003) [13].

Conservation agriculture, a cropping system originally developed in the Americas and Australia on large-scale commercial farms, is based on three principles: a) minimum soil disturbance, and therefore no soil inversion with the hoe or plough; b) permanent surface soil cover through crop residues and/or living plants; and c) crop rotations with different plant species (FAO, 2002). Numerous studies have highlighted the benefits and challenges of CA (Bolliger et al., 2006; Derpsch, 2008; Hobbs, 2007; Kassam et al., 2009; Reicosky and Saxton, 2007; Wall, 2007); however, only a few studies have focused on the contribution of rotations to soil quality improvements and other benefits of the CA system [14].

CA is a sustainable agricultural system which reduces crop vulnerability to extreme climatic events such as longer dry spell, erosion, high evaporation and can reduces crop water requirement by 30 percent. CA makes better use of soil water and facilitates deeper rooting of crops and rain water infiltration reducing the danger of soil erosion and downstream flooding. In addition, it conserves and enhances biodiversity in the field, and eliminates power-intensive soil tillage, thus reducing the drudgery and labour required for crop production by more than 50 percent for small scale farmers (http://www.fao.org/ag/ca/) [15].

Conservation agriculture for climate change and variability

Climate change has both direct and indirect effects on agricultural productivity including changing rainfall patterns droughts, flooding, land degradation and the geographical redistribution of pests and diseases. Global food security, global environmental preservation as well as farmer level increased livelihood should be the main goals of a sustainable farming system in today's world plagued by degraded soils as a result of unsustainable crop management practices. The multitude of rural farmers as well as the three billion urban consumers must rely on sustainable food production systems for their livelihoods [16].

Climatic shocks can be disastrous, particularly in the semi-arid regions of Ethiopia, and discourage the sustainable adoption of improved seeds and agricultural practices (FAO, 2015). Most of the risks associated with discontinuing adopted technologies originate from the recurrent droughts and dry spells (Kassie et al., 2013) that strongly depress crop yield (Segele and Lamb, 2005). The variable rainfall, coupled with the absence of reliable agro-meteorological forecasts, influences the sustainable use of improved seeds and fertilizer technologies (Kassie et al., 2013). To cope with unfavorable rainfall conditions, farmers use various risk diversion strategies such as desisting from investing in fertilizers and improved seeds (Kassie et al., 2013; Yosef and Asmamaw, 2015), and adjusting the cropping calendar, crop, and crop variety to be grown, practicing intercropping and traditional rainwater harvesting and conservation (Kassie et al., 2013; Biazin and Stroonijder, 2012) practices [17].

Agro-ecosystems generate provisioning services (including food, fodder, fuel and fibre) and provide supporting, regulating and cultural ecosystem services, such as carbon sequestration, nutrient cycling, pest regulation, water retention /purification, and biodiversity (Shennan 2008; Newton et al., 2009). However, agricultural activity may also result in ecosystem disservices that include the loss of biodiversity, nutrient runoff / leakage, and the emission of greenhouse gases (Power 2010; Reynolds et al., 2015). Consequently, additional to increased crop productivity, SI technologies need to demonstrate improved input use efficiencies, and minimal environmental impacts through the conservation of resources and maintenance of soil productivity (Vanlauwe et al., 2011) [18].

Soil quality and C status are important indicators of sustainability. Biomass, a measure of aboveground net primary productivity, provides a proxy for belowground net primary productivity, which is rarely measured. The amount and quality of biomass retained on the field as soil cover or when returned to the field as animal manure plays an important role in the ability of agricultural soils to sequester C and to regenerate their inherent fertility.

Therefore, it is of paramount importance for farmers, small-scale and large, in both developing and developed countries, to employ appropriate crop management technologies that will not only generate cost-effective, stable crop production opportunities and allow varieties to yield well but which will also conserve the integrity and sustainability of the soil resource base while ensuring the efficient use of scarce water resources.

CA has been promoted as an agricultural practice that increases agricultural sustainability, concomitant with a potential to mitigating greenhouse gas emissions (Cole et al., 1997; Paustian et al., 1997; Schlesinger,1999). The global carbon cycle is constituted by a short-term biochemical cycle superimposed on a long-term geochemical cycle [19].

Agronomic practices and cropping systems in sustainable agriculture

The sustainable use of agricultural practices has become an important issue in the development-policy agenda for sub-Saharan Africa (SSA), especially as a way to tackle land degradation, low agricultural productivity, and poverty.

Management acts directly on a part of a plant, a whole plant or a small group of plants in a stand, or else an amount of soil that can be lifted or turned by a person, animal or machine. Each act of management influences the physiological processes of the plants, which in turn modify or regulate the flow of environmental resources – sunlight, water, nutrients – to economic or useful products. Though large machines are used, especially in plantation agriculture and with intensely managed cereals, the animal-drawn plough is often the main means by which the soil is turned and shaped, while the hand-held implement, or the hand itself, sows, weeds, cultivates and harvests (Reynolds and Tuberosa, 2008) [20].

Current agricultural management systems are threatened by increasing competition for ever-scarce water resources combined with continued use by most farmers of highly inefficient irrigation systems. Despite the availability of improved varieties with increased yield potential, the potential increase in production is not attained because of poor crop system management (Reynolds and Tuberosa, 2008).

Low input agricultural production systems and poor agronomic management practices have aggravated soil fertility degradation. Soil water conservation should also be integrated with other improved agronomic practices so that the soil water retained could be used effectively (Kidane and Abuhay, 1997). It was found that ensured soil moisture through the use of tied ridges reduced risk levels sufficiently to make investments in fertilizers, weed control, and improved agronomic practices feasible. Organic amendments such as animal dung and crop residues are largely used for competing uses especially for household energy source instead of being recycled to maintain soil fertility. Burning crop residues is common in Ethiopia due to serious shortage of fuel wood. Historically, Ethiopian farmers have used organic fertilizers (such as farmyard manure, compost, crop residue, and house- hold refuse) for agricultural production. Today, commercial fertilizer use is the dominant input that goes with modern varieties. All of Ethiopia's mineral fertilizer is imported (CSA 2013) [21].

Inorganic fertilizer has immediate benefit, but from the natural resource management and environmental protection point of view efficient management and utilization of crop residues with other organic nutrient sources and the required inorganic fertilizers with correct balance may contribute to the sustainability of agricultural productivity and integrated farming system in the highlands of the country, where soil erosion is serious and the resultant soil fertility depletion is high [22].

Agricultural productivity depends on the use and availability of better agricultural technologies and practices. The government of

Ethiopia has given high priority to agricultural development, natural resource management, and agricultural productivity.

Zero tillage with residue retention results in better water infiltration and soil fertility throughout the plot, avoiding soil degradation as well as reducing plant competition and as such spatial variability. Zero tillage with residue removal resulted in soil degradation i.e. poor structure and incapability of capturing water that enhances spatial variability in soil characteristics which in turn causes spatial variability in crop performance (Govaerts et al., 2007).

In the recent past, cropping systems approach has gained importance in agriculture and related enterprises. A system consists of several components, which are closely related and interacting among themselves. In agriculture, management practices are usually formulated for individual crops. However, farmers are cultivating different crops in different seasons based on their adaptability to a particular season, domestic needs and profitability. Therefore, production technology or management practices should be developed keeping in view all the crops grown in a year or more than one year if any sequence or rotation extends beyond one year. Such a package of management practices for all the crops leads to efficient use of costly inputs, presides reduction in production cost. For instance, residual effect of manures and fertilizers applied and nitrogen fixed by legumes can considerably bring down the production cost if all the crops are considered than individual crops. In this context, cropping systems approach is gaining importune [23].

Developing soil management practices, which store and conserve as much rainwater as possible by reducing runoff and improving infiltration opportunity time and increase the water storage capacity of the soil profile is essential in the sem-arid of Ethiopia. Compost and conservation tillage can result in yields compared to chemical fertilizer. These two organic farming techniques can create a win-win situation, where farmers are able to reduce production costs, provide environmental benefits, and at the same time increase their yields. This means they are also used to reverse extensive land degradation in Ethiopia (Edwards et al., 2007). Determining the timing and frequency of tillage for each area and crop type would help to improve productivity.

In Ethiopia low water use efficiency and water scarcity characterize the dominant rainfed agricultural production system. Improving water production system is among the ways of overcoming the water scarcity challenge. The effect of rainfall on soil erosion and the associated soil nutrient losses is expressed by the widespread of poor soil fertility and crust prone soils of cultivated land (Breman et al., 2001). Insitu water conservation system such as tillage practices and tied-ridging contributed for improving crop establishment and grain filling and thereby resulted in higher yield and yield components of sorghum as compared to zero tillage and the traditional ridging [24].

Thus, the interaction between the high yielding potential of the cultivars and favourable agronomic conditions was realized, leading to substantial yield increase (Kidane and Abuhay, 1997). Tied ridges were also stated as effective in controlling runoff and increasing the infiltration opportunity time. On the other hand, conventional tillage with or without farmyard manure resulted in controlling only about 40% of the runoff loss (Kilewe and Ulsaker, 1984) [25].

Multiple cropping systems, especially those with perennial grasses and trees, appears to be less prone to soil erosion because of better soil cover and more barrier to water and air flows. In addition, make better use of available space for root and canopy growth, recycle available nutrients and water than sole cropping systems. Crop rotation and intercropping practices integrated with in situ water conservation methods are used in sustainable crop production. Integrating intercropping practice to Tied-ridge and zero-tillage can maximize growth resources use and increase crop production. This is more efficient when component crops differ greatly in growth duration and simultaneous planting of haricot bean than delayed intercropping haricot bean to the maize system. So that their resource requirement for growth occurred at different times (Abuhay et al., 2016; Hailu, 2015) [26].

Crop rotation for sustainable agriculture

Crop rotation refers to recurrent succession of crops on the same piece of land either in a year or over a long period of time. Component crops are so chosen so that soil health is not impaired or Crop rotation refers to growing different crops in succession on a piece of land in a specific period of time with an objective to get maximum profit from least investment without impairing the soil fertility. This may also be defined as the repetitive cultivation of an ordered succession of crops (or crops and fallow) on the same land and one cycle may take one or more years to complete.

Maize and legume are planted by small scale and commercial farmers in either monocropping, intercropping or rotational cropping as strategy for improving food security.

Rotations have also been associated with positive soil fertility effects on succeeding crops especially when nitrogen-fixing legumes are involved (Giller, 2001). Substitution of nitrogen fertilizers through biological nitrogen fixation by legumes in rotations can be a huge benefit to resource-constrained farmers, who may not be able to purchase inorganic fertilizers (Maltas et al., 2009).

Rotations may improve soil quality and deep rooting crops can lead to better soil structure, aggregation and pore continuity, with positive effects on infiltration and soil moisture in rainfed agricultural situations (Shaxson and Barber, 2003). Better nutrient distribution in the soil profile could be a consequence of exploitation of the root zone in different layers through rotation of crops with different rooting depths. Root exudates from some crops may enhance soil structure benefiting other crops in the rotation.

An increase in soil biological activity due to increased soil organic matter and the populations and diversity of soil fauna and flora may have further beneficial effects on crop growth. In CA systems, a balanced rotation is crucial to produce and maintain sufficient surface residues. One common example is a rotation of crops whose residues have a high C:N ratio (e.g. cereals) and break down slowly with crops with low C: N residues that are short-lived (e.g. legumes) but enhance soil fertility (C. Thierfelder and P. C. Wall, 2010).

Rotations may play an important role in diversifying farmers' incomes and spreading the risk of crop failure (Helmers et al., 2001). Price fluctuations of different crops generally differ, and therefore financial returns can be stabilized by producing diverse crops. The design of crop rotations, and the sequence of crops within the rotation, will depend largely on overall financial returns, market demand for specific crops and market prices. Farmers often rotate crops with different peak labour requirements (i.e. maize before sweet potatoes, sunflower and beans) to spread the need for farm labour. In cereal-legume rotation the positive N response of the cereal has been attributed to the transfer of biologically fixed N, to N-sparing under the antecedent legume, and to less immobilization of nitrate during the decomposition legume residue [27].

Intercropping system for sustainable agriculture

Intercropping is the simultaneous cultivation of more than one crop species on the same piece of land is regarded as the practical application of basic ecological principles such as diversity and competition. It develops energy efficient and sustainable agriculture.

It was reported that the productivity of intercropping mainly depends on rainfall condition, and might also be affected by planting pattern and variety selection. With years of adequate rainfall, light availability across the canopy of intercrops would become the main factor for total productivity (Munz et al., 2014). This is related to the arrangement within intercropping (Gao et al., 2010) and the selection of intercrops varieties as well.

Intercropping is a widely used cropping practice in various ecozones of Africa, but due to increased market orientation in legume production, over the last years more and more area is replaced by monocropping, resulting in increasing problems with pests and diseases (Trenbath, 1993; Fininsa, 2001). Intercrops are better than monocrop cultures because they yield more, protect against risks of drought and pests, even out the distribution of labour requirements, and provide a more balanced human diet (Vandermeer, 1990).

Intercropping: Growing two or more crops simultaneously on the same piece of land with a definite row arrangement.

Sole cropping: One crop variety grown alone in pure stand at normal density. It is also called solid planting.

Row intercropping: Growing two or more crops in the same piece land simultaneously with definite proportion in rows.

The base crop, necessarily in distinct row arrangement and its recommended optimum plant population, is suitably combined with the additional plant density of the associated crop.

The objective is the intensification of cropping both in time and space dimensions and to raise productivity per unit area by increasing the pressure of plant population. It has better utilization of growth resources than sole cropping. Generally, legumes and non-legumes are grown. The advantages associated with intercropping are: (i) additional income from the companion crop, (ii) if the principal crop is damaged due to unfavorable conditions like drought, flood, epidemics, etc., companion crop may give sustenance income, (iii) legumes grown as companion crops always benefit the principal crop through N-fixation and also utilizes soil moisture from deeper soil layers, (iv) quick growing companion crops always suppress the harmful weeds thriving in the inter-spaces of the principal crops, (v) gainful utilization of the labourer by increasing more man days employment potential, (vi) better utilization of growth resources–nutrient, water, light and space, (vii) less incidence of insect pests and diseases attack, and(viii) less erosion losses. At the same time, there are several disadvantages of intercropping as (i) the fertilizer management is difficult because the nutrient requirement of the crops is different, (ii) difficulty in harvesting because of different seeding time of crops, and (iii) there are certain combinations which suppress the growth of another crop and may be conducive to insect pests and diseases.

Disadvantages of intercropping include the competition for light, water and nutrients between crops, which lead to reduction of yields (Cenpukdee and Fukai, 1992). A serious disadvantage of intercropping is due to different requirements for fertilizers, herbicides and pesticides of component crops. In the intercropping, mechanization is almost impossible (Vandermeer, 1990). The other disadvantage of intercropping is higher labour requirements during inter-row cultivation of crops. Farmers have to increase labour input for removing weed on intercropping rows with hand hoes (Osman et al., 2011).

Successful results from intercropping can be obtained provided a suitable companion crop is selected to grow with the main crop. Before putting any intercrop with the main crops like sugarcane, maize, sorghum, bajra, it is very essential to know the prerequisites of the companion crops such as soils and water requirement compatibility: competition for space, sunshine and air, compatibility for pests and diseases; duration and yielding potential and time of sowing and harvesting.

One of the most important strategies to increase crop production in smallholder farmers in the semi-arid areas is development of improved cropping system that intensifies land use efficiency and can make effective use of growth resources (water, nutrient, light, etc.).

Intercropping is one of the cropping systems practiced for higher crop production advantages per unit area. The vital features of intercropping systems are that they exhibit intensification in space and time, competition between and among the system components for light, water and nutrients and the proper management of these interactions. In light of these the system is considered among the agricultural practices associated with sustainable crop production (Tolera, 2003).

Increased crop production (over yielding) often observed in intercrops compared to sole crops has been attributed to enhanced resource use (Szumigalski and Van-Acker, 2008). For intercropping to be more productive it is recommended that component crops differ greatly in growth duration so that their resource requirement for growth resources occurred at different times (Hailu,2015). It is strongly believed that if legumes are intercropped in a timely manner, competition with the companion crop (maize) for light, water and nutrients can be minimized.

According to Banik et al., (2006) the advantages of intercropping include soil conservation, lodging resistance, and weed control over the monocropping. Mpangane et al., (2004) reported that intercropping is a common practice in smallholder farming systems. It was further indicated that, introduction of leguminous crop species into cropping systems had been recognised as an important approach to soil fertility improvement (Mpangane et al., 2004). Since intercropping increases light interception, it reduces growth of late emerging weeds (Takim, 2012).

Besides the improvement of soil fertility, intercropping raises ambient temperature limiting the chance of frost damage, and increase protection of the ground against sunlight and impact of high-intensity raindrops, so that erosion is impeded. The increased rooting of mixed crops, usually extending to deeper levels than would be seen with single crops, helps to hold soils together (Yadav J.S.P. and G.B. Singh, 2000).

Legume and cereal intercropping ameliorate soil fertility through the fixation of atmospheric nitrogen by the legumes. Moreover, intercropping increase the crop residues which returned back to the soil in different mechanism. For instance, livestock fed on the crop residues also apply additional fertilizer to the soil in the form of dung.

Competition for soil N between the cereal and legume components of the intercrop often results in the legume deriving a greater proportion of its N from N2 fixation, as demonstrated with pigeon pea/cereal intercrops (Sakala et al., 2001). The extent to which growth and the total amount of N2 fixed by the legume crop decreased in the intercrop depends on the degree of the complementarity between the crops.

Optical sensors and NDVI

Optical sensor is playing an important role in monitoring and controlling crop management systems. With this technology farmers can control his crop without soil disturbance and plant damage. NDVI tell us how our crop is healthy and moisture sensor communicates information about the level of moisture present at certain depths in the soil.

The normalized ratio of near-infrared reflectance to red reflectance, called the NDVI has been shown to be a sensitive indicator of biomass and leaf area in several crops, which can be used to track crop development over the season. NDVI has been used to evaluate plant nitrogen status (Rambo et al., 2010; Karki, 2013), chlorophyll content, green leaf biomass and grain yield (Shanahan et al., 2001; Inman et al., 2008; Solari et al., 2010; Karki, 2013). Because crop yield is generally correlated with canopy development, this index can be used to develop a relationship to yield. Once a relationship between yield and NDVI is developed, then farmers can predict their yield earlier in the growing season and therefore, better harvest management, planning of inputs, and other more effective management can be achieved. Areas of greater yield potential can be accurately identified by using NDVI early in a growing season.

Modern agriculture is driven by continuous improvement in digital tools and data. It is possible to use scientific data and technology to improve crop yields and keep up-to-date with cutting edge method of farming. Optical sensor playing an important role monitoring and controlling crop management systems. With this technology farmers can control his crop without soil disturbance and plant damage. NDVI tell us how our crop is healthy and moisture sensor communicates information about the level of moisture present at certain depths in the soil.

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Soil moisture and NDVI

Soil water availability is one of the major factors limiting crop production worldwide, especially in arid and semi-arid environments. Soil moisture varies spatially and temporally due to soil type; temperature, precipitation, vegetation, and land use practices (Wu and Yang, 2006).

Many physiological factors could be involved in the drought stress injury (Jiangand Huang, 2001) which may promise for characterizing drought resistance in screening studies. For example, water stress can be caused increase of stomata close and photosynthesis inhibit. Also, water stress induced a significant decrease and increase in chlorophyll contents (Gibon et al., 2000).

Soil fertility was defined as the capacity to sustain plant productivity and quality of water and air (Wang et al., 2014). Smallholder farmers rarely have sufficient cash to invest in organic or inorganic fertilizer to keep soil fertility. Legume-based intercropping has been indicated to increase the soil organic matter contents, through sequestering atmospheric carbon (Dolijanovićet al., 2013). Additionally, organic matter has shown to increase the structural stability of soil and the resistance to rainfall impact (Sileshi and Mahongoya, 2006). By integrating legumes into maize cropping systems, it added considerable amounts of organic matter into the soil and further mitigated land degradation (Sileshi et al., 2012).

Daughtry et al., (2000) suggested that changes in surface soil moisture significantly contribute to differences in crop canopy reflectance (even for homogeneous canopies), making plant stress identification and quantification more challenging. Results by Eklundh (1997) indicated that 10% and 36% of variation in NDVI values could be explained by variation in rainfall on 10-day scale and monthly scales. The author noted that the attempt to use rainfall data to predict vegetative growth may be constrained by variability in soil characteristics (i.e. soil type, soil water holding capacity), as well as rainfall pattern (i.e. duration and intensity) (Table 1).

Soil water content is important for estimating crop yields. Traditional reliance on a close relationship between soil characteristics and crop production means that soil testing must be performed in order to improve management decisions. One major drawback of the soil-based methods is that it is costly; thus, soil testing is rarely practiced by farmers including both in the U.S., and Australia (Zhang et al., 1998; Robertson et al., 2006).

soil properties such as plant available water capacity (PAWC) is an important parameter, which helps to manage problem areas within a field, assists in improving site-year specific grain yield estimation, as well as to improve fertilizer recommendations. Relying on the soil classification maps to estimate PAWC, however, clearly ignores spatial and temporal variability that is known to exist within a single soil type within and across agricultural fields.

Soil moisture conservation is one of the cardinal principles of soil management in rainfed areas with considerable potential for increased productivity. Moisture retention affects soil quality and plant moisture content of soil is one of the essential parameters that determines soil characteristics (Nyatuame and Nartey, 2013).

It was further indicated that soil with high percentage of organic

Table 1: The effect of tillage types on soil water content at different soil depth at Physiological Maturity.

Tillage	0-100mm	0-200mm	0-400mm	0-600mm	0-1000mm
CA	5.92	10.06a	12.3a	13.6	16.2
CP	7.98	9.11b	10.8b	16	11.8
SEM (±)	4.291	0.695	1.23	0.72	0.94
CV (%)	17.6	8.9	13.1	8.4	11.6

matter and natural deposits rich in clay content caused an increase in water holding capacity and reduction in evaporation (Parikh and James, 2012).

Soil nitrogen and NDVI

Nitrogen is important nutrient in determining crop growth and yield. Nitrogen fertilization rates in cereal production systems are generally applied uniformly based on field- level average soil available N status and a specified N requirement based on the grain yield goal. It is hard to predict optimal N rates because they can be highly variable between seasons, depending on weather conditions and soil N supply (van Keulen et al., 1989).

Any of the factors producing large-scale variation in soil nutrients can also be active on small scale. The effects of vegetation and leaching normally interact to live a more ordered and very wide spread variation pattern soil zone except in soils where intense earth worm activity causes continuous mixing or in ploughed or otherwise disturbed soils plant roots brought up minerals from deep layers which are then deposited on the surface as litter rain fall moves ions down the profile again but since the soil physically inert it reacts with some ions more than others, giving characteristic horizons these may vary widely in PH nutrient content and organic matter and provide distinct soil environments within a single soil profile allowing species with different habitat requirements to co-exist(Boddey et al.,1991).

Variable N management is one of the most promising practices of precision agriculture to optimize nitrogen-use efficiency (NUE) and decrease environmental impact of agriculture. Sensor-based measurements can be used efficiently for variable N application in cereal crops when N is the main growth-limiting factor. However, if yield patterns are spatially and temporally stable over multiple years, the causes for spectral variability within the field must be adequately understood before sensor-based variable rate fertilization can safely be used to reduce or optimize N side-dressing in cereals. In these cases optical sensor systems should be used carefully, because they can lead to unwanted increases in soil N surplus and thereby increase the risk of groundwater pollution dry years, less N is needed in zones with high risk of drought, since optimum yields would be depressed by water limitations (Zillmann et al., 2006).

Crop requirements in general and maize N requirements in particular change from year to year, from field to field, and within fields (Mamo et al., 2003). Thus, quantifying the optimum in-season N requirement is an important step toward an economically and environmentally viable corn production system (Varvel et al., 1997). High levels of NO3–N in the groundwater have been attributed to agricultural practices in the south- eastern Coastal Plain, making groundwater NO3 contamination a regulatory and social issue threatening regional crop production. Nitrate losses from fertilizer use can be minimized by matching fertilizer N rates and timing with the specific needs of a crop, thus mitigating a potential source of surface and groundwater pollution (Ferguson et al., 2002).

Traditional methods of estimating in-season optimum N requirements for maize are based on soil testing tissue N concentrations, and chlorophyll concentration or leaf greenness (Varvel et al., 1997). However, these methods require multiple samples to be taken, can be expensive and time consuming, and often produce inaccurate estimates of crop N requirement. There is a need for faster, more accurate, and possibly more economical methods such as NDVI is needed for collecting crop information for estimating in-season N requirements. While yield predicted from Optical sensor (Shanahan et al., 2001) can be used to indirectly estimate N requirements, a more accurate method might be to use spectral reflectance to directly measure corn N requirements.

According to Liben et al., (2018) NDVI was greatest with maize–soybean intercrop and with the rotation under CA and the intercrop under CCP during the vegetative and grain fill to dough stages, and least with maize–soybean rotation during the vegetative stage and with maize monoculture during the grain fill to dough stage.

The NDVI handheld sensor as a tool to monitor crop growth and development

In both natural and agricultural conditions, plants are frequently exposed to environmental stresses. Some environmental factors, such as air temperature, can become stressful in just a few minutes; others, such as soil water content, may take days to weeks, and factors such as soil mineral deficiencies can take months to become stressful. Nevertheless, whether the constraint exerted by the environment is the shortage of a resource, the presence of a toxin, an extreme temperature, or even physical damage, plant responses usually take the form of changes in the rate and/ or pattern of growth, since growth is a synthesis of metabolic process including those affected by the environment.

Maize yield potential varies considerably from year to year in the same field as a result of the combined effects of variation in solar radiation and temperature in irrigated systems as well as rainfall in rainfed systems. In-season crop model predictions can be used to guide management and marketing decisions, along with other sources of information, common sense, and experience (Dobermann and Yang, 2004). The NDVI is an indicator of in-season crop performance (Govaerts et al., 2007b; Verhulst et al., 2011) (Table 2).

Spectral reflectance of a crop differs considerably in the near infrared region (λ=700– 1,300 nm) and in the visible red range (λ=550–700 nm) of the electromagnetic spectrum. Near infrared radiant energy is strongly reflected from the plant surface and the amount of reflectance is determined by the optical properties of the leaf tissues: their cellular structure and the air–cell wall–protoplasm–chloroplast interfaces (Kumar and Silva 1973). These anatomical characteristics are affected by environmental factors such as soil moisture, nutrient status, soil salinity and leaf stage (Ma et al., 2001). The contrast between vegetation and soil is at a maximum in the red and near infrared region. Therefore, spectral reflectance data can be used to compute a variety of vegetative indices which are well correlated with agronomic and biophysical plant parameters related to photosynthetic activity and plant productivity (Ma et al., 2001; Adamsen et al., 1999). The NDVI is successful in predicting photosynthetic activity, because this vegetation index includes both near infrared and red light. Plant photosynthetic activity is determined by chlorophyll content and activity.

Govaerts et al., 2007a also stated that NDVI has been correlated to plant physiological parameters, crop yield and biomass production, rainfall and soil moisture. However, rather than exclusively reflecting

Table 2: The effects of tillage types on maize normalized difference vegetative index at different maize growth stages.

Tillage	Vegetative	Tasseling	Grain filling
CP	64.667a	82.000a	70.667b
CA	60.333b	80.889b	75.222a
SEM+	0.27	0.0786	2.0382
CV%	27.31	8.38	13.29

CP, conventional practice of tillage and crop residue removal; CA, conservation agriculture with no tillage and residue retention the effect of one parameter, the NDVI has to be considered as a measurement of amalgamated plant growth reflecting various plant growth factors.

Crop growth and development as well as yield are the integrated evaluators that show the efficiency of the chosen agricultural management system within the boundaries of the agro-ecological environment.

Any crop cultivars selected for the given agro-ecological zone, will act as an integrated evaluator of all environmental factors thus showing how management influences and determines resource-use efficiency. Crop performance was measured during the 2004, 2006 and 2008 crop cycles with an optical handheld NDVI sensor in the different management treatments of a long-term sustainability initiated in 1991 by CIMMYT by incorporating different tillage practices (zero tillage compared to conventional tillage), residue management (residue removal and retention) and crop rotations (mono cropping vs. a maize/wheat rotation). Based on this long-term experiment the long-term effects of tillage, residue management, and crop rotation on crop yield, on physical and chemical soil quality, on root rot and nematode populations, plus the interactions and effects on yield of root rot, nematodes, and water dynamics and infiltration is observed. Zero tillage with residue retention and crop rotation resulted in a soil with good physical, chemical and biological qualities, and high, stable crop yields, compared to conventional tillage and zero tillage without residue (Govaerts et al., 2005, 2006a, b, 2007a, b, c, 2008a, b, and 2009) [28].

Conclusions

Crop production systems which improve soil fertility and yield through conserving resources, environmentally non-degrading, technically appropriate, and economically and socially acceptable was suggested for regions with poor soil and erratic rainfall.

Conservation agriculture played a vital role in terms of maize growth and yield. Rotational and intercropping under conservation agriculture were very advantageous as compared to monocropping under conventional crop production. Crop rotation and intercropping practices integrated with in situ water conservation methods are used in sustainable crop production. Integrating intercropping practice to Tied-ridge and zero-tillage can maximize growth resources use and increase crop production. Crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources and with minimal impact on the environment. Only by doing this will food production keep pace with demand and the productivity of land be preserved for future generations.

Optical sensor is playing an important role in monitoring and controlling crop management systems. There is a need for faster, more accurate, and possibly more economical methods such as normalized difference vegetative index (NDVI) is needed for collecting crop information for estimating in-season N requirements. Because NDVI is an indicator of in-season crop performance. Optical sensor is indispensable for ecological and conservation biological applications and will play an increasingly important role in the future.

Established Optical sensor systems provide opportunities to develop and apply new measurements of ecosystem function across landscapes, regions and continents.

The productivity of the system could further be improved and sustained by planting maize and haricot bean simultaneously which increased productivity of both maize and haricot bean by avoiding competition between the species during early stand establishment. Farmers should therefore, be encouraged to practice soil moisture conservation practices together with intercropping maize and haricot bean to sustainably increase productivity of the system and optimize use of resources.

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