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Conservation Agriculture: Research Status, Opportunities and Challenges in Dryland Areas of Pakistan

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Abstract

Soil degradation, climate change and increasing cost of inputs are serious challenges for crop production in dryland areas of Pakistan. Mismanagement of natural resources through clean cultivation and intensive tillage are also worsening the situation. Therefore, it is the need of time to search alternative systems. Conservation agriculture (CA) is an emerging technology, which serves as an alternate system has been successfully adopted worldwide for sustainable agriculture, to improve soil properties, mitigate climate change, enhance crop yield and reduce input cost, but dryland areas of Pakistan seem to have missed the opportunity. The accessible information indicate that research study so for conducted in dryland areas of Pakistan are short term and that conservation agriculture (CA) has potential to improve soil structural stability by enhancing organic matter contents, provide equal yield and economically benefit by reducing input cost. There is a need to establish long term, multi-location and collaborative research experiments on different aspects of CA along with the use of computer based models for long term simulations. On farm practice of CA is scarce due to social hindrance, unavailability of local ZT drills, alternative uses of residue. There are big opportunities of CA in dryland areas of Pakistan as climate, soils and crop diversity are conducive to that. Promotion of CA can be enhanced by encouraging local manufacture of zero tillage drills and on farm trainings of the community. CA is the need of hour to combat desertification and provide a healthy environment for coming generations and resource poor farmers of dryland areas of Pakistan.

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Introduction

Pakistan is situated in the north - western South Asia, between latitudes of 23.5° N to 37° N and longitudes 61° W to 76° W. It is surrounded by India in Southeast, China in the north, Afghanistan in northwest, Iran in the west and Arabian Sea in the south (SOER, 2005).

The dryland agro-ecosystems of the country encompass variety of landscapes such as Pothwar plateau, upland of Khyber Pakhtunkhwa, Balochistan plateau and desert of Cholistan. The climate of these regions is mostly characterized as arid to semi-arid while a small portion falls in humid and sub-humid categories. The most of the area is very hot in summer and very cold in winter with four common seasons of winter, spring, summer and fall. Rainfall is inadequate, erratic and about 70% of the rain is received during monsoon (July-September) in the form of torrential storms with exception at Balochistan where winter rains dominate. Two most important cropping seasons are *Rabi* (winter) and *Kharif* (summer) with different cropping patterns. In *rabi* wheat and gram and in *Kharif* Millet, sorghum, maize and pulses are grown. The soil textures of these areas are mostly silty loam and sandy loam with Aridisols and Inceptisols as common soil orders.

Pakistan's dryland areas are facing numerous problems such as desertification, land degradation, structural instability and loss of natural resources (Zia *et al.* 2004). Higher evaporation than precipitation, alkaline pH, accumulation of excessive salts and soil surface crusting are other serious problems in these areas (Rafiq 1990). Commonly a hardpan is observed beneath the soil surface due to intensive tillage and continuous plowing at same depth, which restricts the movement of soil water and plant nutrients in the deeper profile layers. The plow-pan also decreases water infiltration and thus encourages runoff losses (Razzaq *et al.* 1989). Soil water conservation in the soil profile is the major challenge in dryland farming systems (Campbell and Akhter 1990).

One of the major reasons for the above cited problems is low organic matter content of these soils. The loss of organic materials in these areas is very fast due to high temperature in summer, over grazing, deforestation, clean cultivation and intensive tillage with moldboard plow. Further the low cropping intensity and lesser biomass of crops due to water stress, inadequate availability of essential nutrients, weed infestation which ultimately results in less return of organic matter to soil. These anthropogenic and natural factors not only degrade the quality of soil but also contribute to green house gas emissions and thus the climate change that ultimately results in flooding, drought, snowfall and some other drastic events. These mismanagements of natural resources and increasing population pressure promote landlessness and small holder land farming systems. The increasing cost of fuel and other farm inputs are also the critical issues for resource poor farmers. All the above cited problems ultimately affect crop production and due to that potential yields are very low in dryland areas of Pakistan than some other countries.

A few years back, the farmers of dryland areas of Pakistan were using tine cultivator as traditional practice, but in the decade of 1980-90 Barani Agriculture and Rural Development Project (BARD) encouraged the adoption of moldboard plow, especially in the uplands of Pothwar. Most of the literature reported by BARD showed that intensive tillage stored higher soil moisture, decreased bulk density and increased crop yield (BARD 1985-89, Campbell *et al*, 1987). But the long term application of conventional tillage has shown significant economic and environmental drawbacks. From an economic point of view high energy and labour costs ultimately lead to higher cost of production (Košutić *et al.* 2006). From an ecological point of view, disadvantages of intensive tillage systems are increased soil compaction caused by an excessive number of machinery passes, plow pan, systematic reduction of soil organic matter and greater susceptibility to soil erosion (Birkas 2008).

Significant CO_2 emissions from the combustion of large amounts of fuel consumed in the intensive tillage is also an environmental issue (Filipović *et al.* 2006). After a 5 year study (Akhter *et al.* 2002) in Pothwar, northern Punjab dryland found that use of the moldboard plow destroyed soil structure and reduced number of larger pores. As a result of worldwide recognition of huge problems associated with moldboard plow, now it is the need of time to explore alternative systems which not only sustain the quality of soil but also provide sufficient yield by reducing input cost of farmers and help mitigate climate change by carbon sequestration.

Conservation Agriculture (CA) system is being advocated worldwide for sustainable agriculture to improve the health of soil and provide sufficient yield while reducing input cost. Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment (FAO 2011). Three main pillars of CA are i) minimum soil disturbance ii) residue cover and iii) crop rotation. It was initiated in the United States of America in 1930 with the theme to overcome dustbowl. New mechanized equipment was developed in 1940 to directly cast seed into soil. It reached Brazil In 1970 where the farmers together with scientists transformed it into a new resource conserving technology now known as CA. It developed exponentially as a revolutionary technology in Argentina and Paraguay. Afterward this advancement was taken up by different world leading organizations like FAO and ICARDA.

Through seminars, workshops and research publications, the system has reached the deserts of Africa, central Asia (Khazakhastan) and west Asia (China) (Friedrich *et al.* 2012). In 2011 the estimated area under CA was 125 mha. The countries where CA is not practiced have so far missed the opportunity due to research gap, farmer perception and unavailability of locally manufactured zero tillage drill (FAO, 2008; FAO, 2011.

There are numerous benefits of CA for soil health, crop production, water conservation and recently accentuated environment. In CA systems addition of crop residues play a vital role (Loveland and Webb, 2003) that interfere with soil physical, chemical and biological properties (Dexter, 2004). It increases and retains organic carbon in soil (Franzluebbers, 2002; Zibilske *et al.* 2002), improves soil water infiltration, decreases soil surface loss through surface cover and improve soil water and nutrient conservation (Franzluebbers, 2002). The CA also makes the soil stable against the deterioration by water and wind erosion (Madari *et al.* 2005; Chan *et al.* 2002). The crop residues on the soil surface also protect the soil from the impact of rain drop and slow down the intensity of runoff by acting as surface barrier (Franzluebbers 2002b; Zhao *et al.* 2007) thereby increasing intake of water into soil profile and increased *in situ* moisture conservation (Shaver *et al.* 2002). Conservation agriculture system not only improves the quality of soil but also sufficiently increase crop yield. Different researchers have reported that crop yield significantly increases under conservation tillage (Hemmat and Eskandari, 2006; Huang *et al.* 2008). Ling *et al.* 2011 after a review of CA in China concluded that CA promotes soil and water conservation by reducing evaporation losses, increasing moisture storage and organic matter content, slowing down the impact of rain drop, reducing water and wind erosion, depressing weed population and improving soil structure. They also held that CA improves crop production by providing better nutrient cycling and efficient use of profile water. Furthermore CA has been found to be economically better due to reduced input costs of fuel, labor, fertilizer and unnecessary plowing. Although CA interferes with all the environment of soil (Huang *et al.* 2008b), however its effects are site specific and depend on the soil and climate of the area.

The Objective of the current study is to highlight soil desertification and its components which increasing due to mismanagement of natural resources also emphasis the potential of CA in comparison with worldwide scenario. However to review the research status of CA in dryland areas of Pakistan and their effect on soil properties, weed intensification, crop production and economics. Also highlight challenges and opportunities of CA to combat desertification, environmental vulnerability and increasing cost of input.

Status of research on ca in Pakistan

Most of the available literature on CA in Pakistan is from the Pothwar Plateau of northern Punjab and uplands of Khyber Pakhtunkhwa while the evidence from other dry land areas is scarce. The Pothwar Plateau consists of near about 2 mha of which more than 1 mha under cultivation. The Plateau has generally gently undulating surface, locally broken gullies and low hills. The rainfall in this area varies from 500-1000 mm annum. More than 70% of the rainfall received during monsoon (July-September). Summer is very high temperature while winter is very cold. The KP falls in the semi-arid zone. The annual rainfall during the last many years ranged between 200 mm to 1057 mm with an average of about 435 mm. The most humid month is August (76.7mm) followed by March (73.7mm) while June (11.6mm) and October (13.4 mm) are the driest months. The evapotranspiration range is narrow during December to March (36-85mm) and highest in June (202mm). The mean monthly maximum temperature ranged from 17.6 to 39.3 C^o and the minimum temperature from 1.7 to 24.1C^o. The highest monthly temperature is around 43C^o in June and the lowest –30C in December. The average Relative Humidity (R.H) ranges from 54 (June) to 72.6% (August). The research is generally focused on the effects of different forms of conservation tillage on soil properties, crop yield and economic benefits.

Effect on soil properties

As previously mentioned there are multifarious soil related natural and anthropogenic issues in dryland areas of Pakistan that are further aggravated with the use of intensive tillage and clean cultivation. Therefore there is a need to improve the quality of soil by reducing number of plowings, incorporating crop residues and thus increasing organic carbon content. Shah *et al.* (2010) in uplands of Khyber Pakhtunkhwa after three years of an experiment found that NT improved 16% SOC, 10.44% MBC and 16.87% MBN over the CT tillage. They also reported higher SOC and TN with residue return than residue removal and intensified cropping than fallow based cropping. Among crops legume-cereal rotation promoted SOC than cereal-cereal rotation. Shafiq *et al.* (1974) took micrographs of sequential exposures of soil crust perpendicular visual observations suggested that the soil crust taken from conventional and deep tilled plots had fewer and smaller voids than zero tilled plots. The pores were open to the soil surface and their edges were sharp in samples from zero tillage plots. (Anwar-ul-Hassan, 2000) after a comprehensive review about arid and semi-arid areas of Pakistan reported that surface soil crusting is a serious problem over 2.3 mha of dryland areas of Pakistan (Rafiq 1990) due to low organic matter, high silt content and sodicity. He suggested that adoption of different management practices such as application of surface mulches and increasing organic matter contents would help to overcome the problem. Mulching which part and parcel of CA has been found to control soil crusting. Under rainfed conditions in the Pothwar area (Nizami *et al.* 1995; Nizami and Salim 1997) studies were conducted to evaluate the effect of crusting on crops. In first study, four soil series were investigated. Then six soil series (including these four) namely Gulian (SiCL), Khaur (SiCL), Missa (SiL), Pir Sabak (SiL), Balkassar (SL) and Khair (SL) were selected for the second study. The soil treatments were: Fertilizer without hoeing (A), farmyard manure with no hoeing (B), fertilizer + grass mulching without hoeing (C) and fertilizer with hoeing (D). The applied nutrient status of all the treatments was kept uniform. Soil crust intensity decreased from 6.3 to 1.5 kg cm-2 as the texture changed from SiCL to SL, while increased with an increase in silt and clay contents and was inversely proportional to organic matter and soil water contents. With an increase in soil crust intensity, the plant population decreased. It was concluded that soil structure and aggregate stability can be improved by using organic manures. The highest increase (81-144%) in grain yield was noted with hoeing on the Guliana, Khaur and Missa soil series. On the Pir Sabak soil, mulching and hoeing showed similar response, and treatment C was the most effective on the Balkassar and Khair (SL) soils. An economic analysis showed that hoeing was the best treatment for managing crust in the Khaur, Guliana and Missa soils; mulching and hoeing were equally good for Pir Sabak soil and mulching was the best for Balkassar and Khair (SL) soil series, i.e. site-specific response to treatments. In rain-fed agriculture, soil, water storage is the main issue due to low rainfall and high evapotranspiration. (Ijaz *et al.* 2007) conducted experiments using different tillage practices with and without application of straw mulch. The MT showed significantly low fallow efficiency and water content at wheat sowing in the two year study than conventional practices (15-23%). However the mulch 4 Mg ha^{-1} and no-mulch plots did not show significant differences for soil moisture storage. They suggested that further research is needed to find out the best rate of wheat straw mulch and ways of residue management to withstand quick decomposition under extreme summer temperatures or the area for a longer period especially for conservation tillage system. (Shafiq *et al.* 1987) compared chisel plow and zero tillage with tine cultivator. They found that chisel plow before the onset of the monsoon had the highest soil moisture content and least bulk density while ZT had the lowest moisture and highest bulk density. A field study was conducted by (Mohammad *et al.* 2010) under the semi arid conditions of Khyber Pakhtunkhwa. The experiment comprised of The experiment comprised of two tillage i) conventional tillage (T_1) and ii) no-tillage (T_0) and two residues i) wheat crop residues retained (+) and ii) wheat crop residues removed (-) treatments. Basal doses of N @ 20: P @ 60 kg ha-1 were applied to mungbean at sowing time in the form of urea and single super phosphate respectively. Labeled urea having 5% 15N atom excess was applied @ 20 kg N ha-1 as aqueous solution in micro plots (1m2) in each treatment plot to assess BNF by mungbean. Similarly, maize and sorghum were grown as reference crops and were fertilized with ^{15}N labeled urea as aqueous solution having 1% ^{15}N atom excess @ 90 kg N ha-1. They observed that zero tillage with residue retention improved biological nitrogen fixation and water use efficiency under rain fed condition. The maximum amount of N_2 fixed by mungbean (82%) was derived in no-tillage with wheat residue retained treatment. These results suggest that BNF and WUE in the rain-fed environment can be improved with minimum tillage and crop residue retention. Further evidence came from the field study carried out by (Ali *et al.* 2013) during 2005 through 2007 at two locations (Rawalpindi and Fatehjang) in Pothwar, Pakistan to compare minimum tillage with conventional tillage practices for yield performance and nitrogen fixation in mungbean (*Vigna radiata*). The treatments including Minimum Tillage (MT), Conventional Cultivator (CC) and Moldboard Plow (MP) were laid out in a randomized complete block design. All the tillage treatments had equivalent profile moisture content at mungbean sowing. The results on %Ndfa (nitrogen derived from the atmosphere) and total N_2-fixed varied with sites. At Rawalpindi site, though total nitrogen fixation slightly decreased with a decrease in tillage intensity, the differences were statistically nonsignificant. The average values were 24, 34, 32 percent for %Ndfa and 15, 19, 21 kg ha^{-1} for total N_2-fixed under MT, CC and MP, respectively. At Fatehjang site, CC had a significantly lower nitrogen fixation than MT and MP. The average values were 40, 12, 49 percent for %Ndfa and 24, 6, 32 kg ha^{-1} for total N_2-fixed under MT, CC and MP, respectively. The results of study indicate that comparable mungbean nitrogen fixation can be achieved by minimum tillage while avoiding current intensive tillage practices in semi arid Pothwar, Pakistan. In the uplands of Pothwar (Nizami *et al.* 1990) compared three tillage practices, i.e. moldboard plow, chisel plow and tine cultivator in different soil series. They reported that influence of different tillage practices was site specific. Chisel plow conserved more moisture in Missa and Balkassar soils while MB plow in Guliana. Chiseling was efficient in moisture conservation where a pan existed in the profile or the soil texture was coarse. In another study at the rainfed area of Khyber Pakhtunkhwa (Mohammad *et al.* 2006) concluded under different tillage practices with the addition, removal of crop residues through crop rotation with different fertilizer levels. The soil moisture contents data recorded with neutron at different growth stages of wheat indicated that similar moisture content in 0-30 cm upper soil was recorded in the tillage and no-tillage treatments. However, at lower depths 30-90 cm the ZT treatment at seedling 1st tillering, 2nd tillering, booting, anthesis, milk development and maturity stages contained 30.4, 24.15, 25.73, 13.81, 44.2, 32.0 and 9.65 mm more water in soil profile than tillage treatments, respectively. Working in the highlands of Pothwar by (Shafiq *et al.* 1994) contrasted direct drilling with two farmer conventional practiced i.e. conventional cultivator, Moldboard. Who found that soil moisture content measured in June, August and December were similar under conventional and no-till treatments. However the infiltration rates measured in the same months were significantly higher under no-till. They also explained the reason that surface vegetation encouraged the breakdown of soil crusting which ultimately reduced the surface runoff and increased vertical flow of water in soil profile. (Hussain *et al.* 2013) compared different tillage practices at the time of wheat sowing and reported that there was no difference in soil moisture content at different stages during wheat crop. In an effort to reduce fallowing in Pothwar, Pakistan, 3 year field experiments were carried out from 2005 through 2008 at three locations (Rawalpindi, Chakwal and Fateh Jang). The tillage treatments; conventional cultivator, moldboard plow and minimum tillage were applied in main plots; fallow, legume (mungbean, *Vigna radiata*) and mulch of wheat straw were used in sub plots. Wheat (*Triticum aestivum*) was planted in all the subplots during winter. The results showed that all the treatment plots had equivalent volumetric water content upto 90cm profile at the time of wheat planting. In a five year study (2004 through 2009) (Mohammad *et al.* 2012) reported maximum N fertilizer utilization 24.1%, 62.7% and 38.0% in wheat were obtained under no-tillage + residues treatment during 2006, 2007 and 2008 respectively. The SOC in surface soil (0-15 cm) was higher in wheat-fallow-wheat and wheat-legume-wheat rotation under no-tillage + residues treatment. (Ijaz *et al.* 2010) and Ali *et al.* (2013) reported in Pothwar that volumetric water content was equal under Moldboard plow (MB), Minimum tillage (MT) and Conventional tine cultivator (CT).

Effect on weed population

Weed infestation is also a serious threat in dryland agro ecosystems and involve reduction of crop production. They not only reduce crop yield, but also deteriorate the quality of product and hence the market value of the crop decrease (Arif *et al.* 2007). They compete with crops for uptake of nutrient, soil water, depress crop and ultimately yield upto 80% (Khan *et al.*, 2004). Tillage plays a critical role in weed management strategies (Mohler and Galford 1997). In the rainfed area of Pothwar (Shafiq *et al.* 1994) in a study reported that the weeds population was remained same under different tillage treatments but the weed biomass was higher in zero tillage plots in fallow as well cropping season. However, (Arif *et al.* 2007) evaluated in a one season study from the rainfed area of Khyber Pakhtunkhwa that weed population was higher under no-till followed by reduced tillage and Chisel plow. They also reported that soil disturbance depress the weed population. Also (Khattak *et al.* 2005) evaluated the effect of different tillage practices i.e. no-till, chisel plow, tine cultivator, moldboard plow and disc harrow in chickpea-fallow rotation on weed population under rainfed conditions of district Karak of Khayber Pakhtunkhwa. After three years of study they reported that chisel plow depressed weed population followed by moldboard plow. The NT had the highest weed density.

Effect on crop production

With increasing population and decreasing land owners the rainfed lands have great potential for contributing to national food productions to meet the food and fiber demand of resource poor masses of country. Crop yield can vary from year to year and are influenced by different factors including soil type, climate and management practices. (Mohammad *et al.* 2006) conducted a study for comparison of farmer's conventional tillage and no-tillage both with residue retention and removal of wheat and oat crops. They reported that there was no significant difference in crop yields and related attributes in tilled and no-till plots. Further, more in the uplands of Pothwar Plateau (Ijaz *et al.* 2007) conducted a two year experiment in which the main treatments were moldboard plow, sub-soiler and conventional cultivator with the addition and removal of straw mulch. The treatments were applied at the start of fallow period and wheat crop was sown during winter. They reported that the minimum tillage and moldboard plow gave averagely 30% higher grain yields of wheat than tine cultivator during both the experimental years. Grain yield was 33% higher in mulch than no mulch. In Khyber Pakhtunkhwa at rainfed conditions of Lukimarwet (Khan *et al.* 2011) conducted an experiment in which zero, reduced, conventional and maximum tillage with different doses of fertilizer N were applied at the time of wheat sowing. The one season study indicated that germination count, grain per spike and 1000 grain weight were similar under all tillage treatments. However the productive tillers and wheat yield were significantly higher with maximum tillage. Also (Khattak *et al.* 2005) in a sandy loam soil of rainfed area of Khyber Pakhtunkhwa compared the effects of no-tillage, chisel plow, moldboard plow, cultivator and disk harrow on chickpea yields. They reported that maximum chickpea yield was obtained under the chisel plow that was 19% higher than the NT that was attributed to better weed control. In a long term field study (2004-09) carried out by (Mohammad *et al.* 2012) in north-west Pakistan the treatments consisted of three rotations: i) Wheat-fallow-wheat (farmers' practice) ii) Wheat- summer legume-wheat and iii) Wheat-summer cereal-wheat with two tillage and crop residues management treatments: i) Tillage (crop residues removed) and Tillage (crop residues retained) and ii) No-tillage (crop residues removed) and No-tillage (crop residues retained). The results revealed that the wheat grain and straw yield in tilled and no till treatments were equal in all the five years. However, every year, crop residues retention significantly enhanced the wheat grain and straw yield. Crop residues with no-tillage resulted in 520 kg ha^{-1} greater wheat grain yield than residues removed treatment. Similarly WUE, N yield and fertilizer N utilization by wheat was increased significantly by crop residues under no-tillage compared to the tillage treatment. The results of the long term study showed that no-tillage + crop residues and legume based rotation treatment were beneficial under the rainfed (dry) conditions. (Shafiq *et al.* 1987) conducted an experiment under the environmental condition of Pothwar to evaluate the effect of zero tillage, cultivator and chisel plow on the yield of wheat crop. They reported that yield was higher under chisel plow than other treatments.

Also (Khan *et al.* 2011) compared the effect of cultivator with moldboard on mungbean yield under the rainfed conditions of Dera Ismail Khan, Khyber Pakhtunkhwa. After a two year study they concluded that yield was higher under tine cultivator than moldboard plow. Also (Razzaq *et al.* 2002) in a three year study at farmer's fields of Islamabad evaluated the effect of moldboard plow, direct drilling and tine cultivator. They reported that yield was higher with moldboard than direct drilling and tine cultivator. Moreover (Mohammad *et al.* 2010) found the effect of conventional tillage and no-tillage with and without residue on mungbean (*Vigna radiata*) yield under the rainfed conditions of Khyber Pakhtunkhwa. Maximum mungbean yield (1224 kg ha^{-1}) was obtained under no-tillage with addition of crop residues. Also (Arif *et al.* 2007) contrasted three tillage treatments i.e. no-tillage, reduced tillage and chisel plow in a rainfed valley of Peshawar, Khyber

Pakhtunkhwa. They concluded that the fodder maize yield was significantly higher under reduced tillage. However in case of groundnut yield has been found to be better with moldboard plow than chisel plow by (Akhtar *et al.* 2005) under rainfed condition of Chakwal, Pothwar. Also (Ijaz *et al.* 2010) were carried out field experiments from 2005 through 2008 at three locations (Rawalpindi, Chakwal and Fateh Jang).

The experimental design was split–plot and treatments were applied as follows: conventional cultivator, moldboard plow and minimum tillage in main plots; fallow, legume (mungbean, *Vigna radiata)* and mulch of wheat straw were used in sub plots. Wheat *(Triticum aestivum)* was planted in all the subplots during winter. The wheat biomass and grain yields were statistically equivalent under all the applied treatments. The average yields were 7.37, 6.19 and 4.27 Mg ha^{-1} for wheat biomass and 3.06, 3.56 and 1.6 Mg ha^{-1} for wheat grain yield at Rawalpindi, Chakwal and Fateh Jang sites. Also (Ali *et al.* 2013) conducted a field study during 2005 through 2007 at two locations (Rawalpindi and Fatehjang) in Pothwar, Pakistan to compare minimum tillage with conventional tillage practices for yield performance of mungbean (*Vigna radiata*). The treatments including Minimum Tillage (MT), Conventional Cultivator (CC) and Moldboard Plow (MP) were laid out in a randomized complete block design. The biomass and grain yields were generally equivalent under all the tillage treatments. The average values were 3.10, 3.19, 3.64 Mg ha^{-1} for biomass and 0.59, 0.58, 0.60 Mg ha^{-1} for grain yield under MT, CC and MP respectively.

Economic efficiency

Increasing costs of inputs such as fuel, fertilizer and seed have rendered the dryland farming a profitless business for small landholders.

Therefore, lowering the input cost of dryland agriculture is the need of the time. Arif *et al.* (2007) compared economics of no-till, tine cultivator and chisel plow. They reported that the no-till with an efficiency coefficient of 1:4 was found to be economically more feasible for resource less farmers although gross margins and gross income were higher with tine cultivator. Also (Ahmed *et al.* 2007) evaluated bed planting, zero tillage and conventional tillage in rainfed area of Islamabad and reported that zero tillage gave maximum net income by decreasing input cost.

Challenge to CA in Pakistan

The above review clearly show the possibility of successful use of CA in Pakistan. However, there are big challenges which hinder quick adoption of CA by farmers which can be summarized as follows:Social hindrance: Farmer's perception is one of the major problems for the adoption of conservation agriculture. Farmers of this area traditionally believe that maximum plowing is useful for utmost crop production. The farmers that do not plow very often are called as lazy and inactive in local community.Residue retention is the 2nd most important principal for successful conservation agriculture but our farmers do not leave any residue for soil surface cover.

They use straw for feeding their animals and use fallow fields for grazing purposes. The livestock is another important sector for rural people to meet their food requirement.CA systems require a specific seed drill e.g. zero-tillage drill, which are not available in the local market. Also the pulling of heavy drill may require a powerful tractor which is not affordable.

There is no technical experience of farmers for initiation of CA. This new advancement needs expertise for shifting from traditional farmer practice to the new system. Also the extension system in the country is not so strong that can help farmers to understand the basics of CA. The chemical herbicides used for control of weeds in CA during fallow and crop periods are costly and generally adulterated. The farmers of dryland areas lack knowledge about preparation and proper use of these chemicals.The Government lacks clear policy for promoting conservation agriculture. Also there is no independent research institute about CA to bridge the research gap between Pakistan and other pioneer countries in CA. There is need of long term, comprehensive and collaborative research on CA that involves soil scientists, agronomists, plant breeders, agricultural engineers and extension workers together. The benefits of CA to soil and crop production take at least five years to appear therefore it is difficult for resource poor farmers to wait and visualize the benefits of CA.

Opportunities

Already successfully practiced in vast arid-semi and arid regions, Worldwide and Pakistani climate is also mostly arid and semi-arid.There are big opportunities for successful adoption of CA in steep slope topographic areas. As the soils of dry land areas of Pakistan are silty loam and sandy loam there is big chance for CA adaptation. In the dry land of Pakistan there is a big chance for adaptation of crop diversification is the third main principal of CA. Optimum soil temperature in different areas promotes soil biodiversity.

Conclusion

Most of research studies from dryland areas of Pakistan are short term and they indicate that different forms of CA increase organic matter contents improve soil structure, provide equal yield and economic benefits by decreasing input cost. Particularly chisel plow performed better in comparison with moldboard plow in most of the investigations. However, there is a need to establish long term, multi-location and collaborative research experiments on different aspects of CA that use computer based models for long term simulations to draw clear conclusions.

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