IMPACT OF COVER CROPS IN IMPROVING AGRO-ECOSYTEMS INCLUDING SUSTAINABLE WEED SUPPRESSION – A REVIEW

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ABSTRACT

Weeds are always considered as one of the serious pests that compete for their growth and development and decline the production in of major crops. Weeds occur in abundance in every cropping system i.e. wheat-rice, wheat- maize and wheat- cotton cropping systems. Herbicides are used in order to minimizet weed infestation, but the use of herbicides or inorganic chemicals against weeds is also developing resistance in weeds to herbicides. Despite that herbicides are also affecting the environment especially human health. Pesticides not only damage the human health but also pollute the air, soil, water and becoming part of food chain. One of the options to minimize weed infestation is intercropping of cover crops between cash crops to reduce the weed suppression. Cover crops are the plants grown inn field in such a way that these plants give soil cover despite it may be incorporated in field or not and also facilities weed suppression, control soil erosion, improve soil fertility and also manage diseases and pests present in that field. Cover crops normally comprise of legumes and grasses. Cover crops lead to be one of the better options that reduce the dose of herbicides and these are harmonious with the objectives of conservation agriculture. Regardless of much importance of cover crops and their worth in agricultural systems, cover crops have certain negative aspects as well. They compete with cash crops for moisture, solar radiation and nutrients which ultimately decrease the return of cash crops. Farmers are still hesitating to grow cover crops in their farming systems due to lack of knowledge about these crops. According to Daily Times, in Pakistan soil erosion is 20% and organic matter is less than 1%. So, cultivation of cover crops helps to minimize the adverse effect of erosion and enhances the organic matter content in soil. Cover crops may decline the yields but cover crops are one of the steps that leads to a sustainable or conservation agriculture.

Keywords: Biocontrol, carbon sequestration, cover crops, sustainable agriculture, weed suppression.

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INTRODUCTION

Weeds are considered as one of serious pests in reduction of yield in major crops of the world (Razzaq *et al.,* 2010; Akbar *et al.,* 2011). Almost 34% of the yield of the crop declines due to weed infestation in the field (Jabran *et al.*, 2015; WSSA, 2018). Weeds occur in abundance in every cropping system i.e. wheat-rice cropping system, wheat-maize cropping system and wheat-cotton cropping system. Having various modes of reproduction in weeds, normally considered as self-grown (Picard *et al.,* 2010). Having faster and rapid vegetative growth massively decline the growth and development of agronomic crop at initial stages of crops (Feil *et al.,*1997). Scientists have reported that high weed infestation results into minimized agronomic yield upto 50% due to heavy weed infestation at initial stages of crop due to competition (Gabriel *et al.,* 2012; Webster *et al.,* 2013). Weeds compete with crops for space, water, nutrients and light for their growth and development and decline the production of horticultural and agronomic crops (Tiecher *et al.,* 2017; Malone *et al.,* 2017; Coniberti *et al.,* 2018). Weeds can compete with crops by absorbing 39% Ca, 24% Mg, 47% N, 50% K and 42% P for proper growth and their survival (Radicetti *et al.,*2016; Tiecher *et al.,* 2017). Weeds are considered as host for numerous insects, pests, diseases and microorganism consequently minimizing the yield and production of crops (Summers *et al.,* 2014; Coniberti *et al.,* 2018). Numerous species of weeds secrete certain poisonous and allelopathic compounds i.e. phenolic (ferulic acid, caffeic acid, cumarins, psorlen), terpeniods and benzoic compound added within soil that inhibits the development of agronomic crops and affects the human beings and livestock i.e. cattle, and buffaloes (Bajwa *et al.,* 2019). Herbicides are used in order to get remedy of weeds infestation (Hozayn *et al.,* 2012). The most cost effective, effectual and time saving options is utilizations of chemicals or pesticides for weed suppression (Ashiq *et al.,* 2006). Current agricultural productions trends are totally centered around herbicides in order to get rid of weeds (Sadeghi *et al.,* 2010). The use herbicides or inorganic chemicals against weeds are also developing resistance in weeds. In recent past the consciousness of herbicides on environment and its awareness to public has been increased (Reddy, 2001). Despite that herbicides are also affecting the environment especially human health (Hamadache *et al.*, 2016). Pesticides not only damage the human health but also pollute the air, soil and water (Kemmerich *et al.*, 2015). Herbicides are becoming part of food chain (Farooq *et al.,* 2011). So, in present situation the most significant target is to produce the food products in which synthetic inputs are less used. For that reason other control measures are required to be taken to control weeds instead of herbicides (Hollander *et al.*, 2007). Weeds cannot be suppressed without herbicides, hence we have to plan such combination of weed management strategies in which we integrate organic and inorganic ways both which reduce the environmental problems and provide maximum output in terms of yield. One of the options is intercropping of cover crops between cash crops rows to reduce the weed competition with the main crops (Pullaro *et al.*, 2006). The current paper gives brief information regarding history, definition and principle of cover crops. Moreover, the current review paper discusses the impact of cover crops on environment, soil, microbes, nitrogen use efficiency and weeds suppression.

HISTORY

Cover crops were used in prehistoric time. During early period of Romans bell beans were habitually cultivated in the vine yards (Strom, 2016). Cover crops were also being cultivated in ancient India and China and it is well documented in texts from 3000 years ago (Martin, 2012). Virgil (70-19BCE) written a book named "A Tomb on All Aspects" also said that alfalfa, clovers and lupine can be used to increase the wheat yield (Snapp *et al.,* 2005). Jefferson and Washington (late 1790s) were considered as founding fathers using grasses and legumes in tobacco, wheat and corn field and they reinstated the exhausted land to minimize emigration along with starvation (Ingel *et al.*, 1998). In 1860's cover crops were cultivated widely in the world. The importance of cover crops was defined in 1st century by Columella in Rome. He said "where no kind of manure is to be had, I think cultivation of lupines will be found the readiest and best substitutes. If they are sown around the middle of September in poor soil, and then ploughed in, the following spring, they will answer as well as the best manure" (Martin, 2012).

DEFINITION OF COVER CROPS

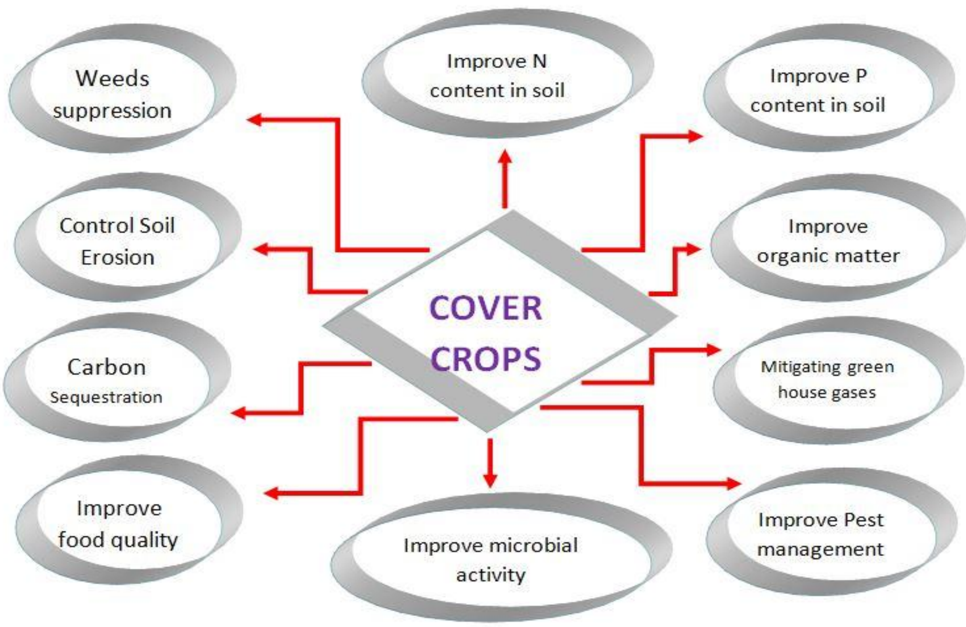
Production of harvestable product is not the main purpose to establish cover crops. "Cover crops are plants grown on field in such a way that these plants give soil cover despite it may be incorporated in field or not and also facilitate weed suppression, control soil erosion, improve soil fertility and superiority and also manage diseases and pests present in that field" (Martin, 2012; Haider, 2018).

Cover crops normally comprise of legumes and grasses (Mwangi *et al.,* 2015). Cover crops lead to be one of the better options that reduce the dose of herbicides and cover crops are harmonious with the objectives of conservation agriculture (Reddy, 2001). The selection of cover crops depends on aim of specific agricultural system (Garcia *et al.,* 2015).

PRINCIPLE OF COVER CROPS

The principle of cover crops is to supply soil a cover, which effects the germination of neighboring seeds by changing seeds environment i.e. change in light availability, soil temperature and moisture and other inferences types like allelopathy (Creamer *et al.*, 1996; Jabran *et al.,* 2015).

Following are the benefits of cover crops which are summarized below:



Weed suppression

Cover crops help to suppress the weed population. Table shows the experiment of different scientists which work on cover crops and their results.

Cash crops	Cover crops	Weeds suppression	Source
Organic pepper	Hairy vetch, rye grass oat and common vetch	73%. 70%, 28% and 56% respectively	(Isik *et al.,* 2009)
Cucumber	Sorghum sudangrass, cereal rye, hairy vetch and bare	40, 56, 65 and 372 plants per m^2 respectively	Ngouajioa and Mennanb, 2005)
Coffee	Dwarf mucuna (Mucuna de eringiana)	90.8%	(Martinsa *et al.,* 2015)
Maize	Velvet bean	92%	(Mhlanga *et al.,* 2015)
Potato	Rapeseed and rye grass	<1%	(Campiglia *et al.,* 2009)
Maize and Soybean	Forage radish, hairy vetch and cereal rye	30%	(Welch *et al.,* 2016)
Tomato	Hairy vetch *(Vicia viillosa)*	79%	(Campiglia *et al.,* 2010)
Tomato	Oat, Hairy Vetch and subclover (*Trifolium subterraneum*)	93%, 80% and 35% respectively	(Campiglia *et al.,* 2010)
Cassava	Pumpkin	30-60%	(Weerarathne*et al.,* 2017)
Maize	Yam pumpkin	70%	(Weerarathne*et al.,* 2017)

In the above table#1 facts show that cover crops are one of vital options for weed management in different cropping systems of the world. Sturm *et al.,* (2016) reported that cover crops extracts and their mulches also inhibit the growth of certain weeds like *Stellaria media* L. (chickweed) *Chenopodium album* L. (lamb's quarters) and *Matricaria chamomilla* L. (chamomile). Radish and buckwheat due to expeditious growth considered as better option as cover crop to inhibit the weeds as compared to rest of cover crops like red oat and white mustard (Brust *et al.,* 2014). Yeganehpoor *et al.* (2015) conducted a series of experiments and concluded that clovers are better option as cover crops in maize due to their fast and rapid growth for weed suppression. Cover crops extracts are one of the influential tool used for weed suppression (Ayala *et al.,* 2015). Legume crops like white clover, sub-clover and birds-foot trefoil as cover crops have the ability to be used as effective weed management strategy to control weeds in wheat (Hiltbrunner *et al.,* 2007). White mustard as cover crop in buckwheat has a strong potential of weed smothering (Masilionyte *et al.*, 2017). In potato, soybean and maize crops cover crops like winter rye and hairy vetch were intercropped and observed that cover crops are major cause of weeds suppression in above stated major crops without any decline of yield (Uchino *et al.*, 2012). Sweet potato is also one of the better options as cover crop shows efficient weed suppression in maize crop (Aladesanwa and Adigun, 2008). Finger millet is also one of the options as cover crop as it reduces the weed density in soybean (Samarajeewa *et al.*, 2006). Zucchini yield was also high due to 65 % of weed suppression when roller crimped was grown as cover crop in zucchini crop (Ciaccia *et al.*, 2015). Rye was used as cover crop in organic bean and observed that cover crops suppress the weeds invasion (Evans *et al.,* 2016). One of the valuable approaches for inhibition of weed biomass is cultivation of white mustard and mixture of white mustard and buckwheat was cultivated as cover crops (Masilionyte *et al.,* 2017). Roarty *et al.,* (2017) also planted mustard as cover crops along 11 more cover crops and observed that mustard cover crop plays an important role in weed suppression along with high barley production. Crops like maize, soybean, sweet corn, summer squash, spring cabbage, snap beans and tomatoes show better yield and having less infestation when subterranean clover was as cover crop or living mulch (Ilnicki and Enache, 1992)

MICROBIAL ACTIVITY AND BIO-CONTROL

The application of inorganic fertilizers lessoned the microbial activity in soil (Lehman *et al*., 2012). Cover crops help to improve the symbiosis relationship within the soil. The cultivation of barley as a cover crop between sunflower and maize increased root colonization, length of hyphae and number of arbuscular mycorrhizal fungi spores upto 80% in sunflower and 60-70% in maize (Gonzalez *et al.,* 2016). Carpio *et al.,*(2017) reported the cultivation of herbaceous cover crops in olive orchard to help minimize the losses of biodiversity. Cover crops play an important role to improve microbial activities in soil and beetles population in field, per capita seed predation was 73% increased as compared to plots with no cover crops (Blubaugh *et al.*, 2016). *Paspalum notatum* L. was cropped as cover crop in banana orchard and it was observed observed that cover crop reduced the population of pests like banana weevil in banana field (Carval *et al.,* 2016). Population of microbes especially bacteria are significantly increased in soils where hairy vetch, cereal rye and oilseed radish was grown as cover crops along with organic manures (Fernandez *et al.,* 2016). Continuous mono-cropping decreased the soil nutrient status, but plantation of cover crops enhance the nutrient status of soil and enhance the microbial population, soil phospholipids fatty acid and gram positive bacteria. Mono-cropping plantation systems causes dramatic changes in soil i.e. decreasing organic matter, nutrient cycle, quality of soil, and increase pest attack and environment deprivation (Jacques and Jacques, 2012). Plantation of cover cropsimproves microbial activity in soil i.e. the population og gram positive bacteria and soil phospholipids fatty acid was increased. In direct seeding mulches-based cropping system the activities of soil b-glucosidase and acid phosphatase were considerably higher (Rabary *et al.*, 2008). The population of microbes like bacteria, fungi, protozoa, nematodes, mites and collembolan was greatly increased when white clover was used as cover crop in maize field (Nakamoto and Tsukamoto, 2006). Legume cover crops also enhanced the nematodes population in contrast with cereals cover crop and no cover crops fields (Djigal *et al.,* 2012). Arbuscular mycorrhizae fungi population was increased due to introduction of cover crops in the field which improves the microbial population in soil (Benitez *et al.*, 2016; Detheridge *et al.*, 2016). The enzymes such as urease and dehydrogenase significantly increase in soil where cover crops along with no tillage was practiced (Nivelle *et al.,* 2016). Roarty *et al.,* (2017) planted pea as a cover crops along with 11 different cover crops and concluded that population of earthworm was increased in plots where pea was planted as cover crop and population of earthworm was low where mustard was planted as cover crop and hairy vetch as cover crop also improve the earthworm population in soil (Ashworth *et al.,* 2017). The utilization of cover crops in field trends to improve bacterial diversity especially proteobacteria, actinobacteria and acidobacteria (Lupwayi *et al.,* 2017). In modern cropping system earthworms are vital for improvement of biophysical properties of the soil (Ashworth *et al.,* 2017). Cover crops like legume rye and mustard with compost relatively improved microbial biomass of carbon from 40 mg C kg^{-1}upto 200-250 mg C kg^{-1} that ultimately altered soil food web (Brennan and Martinez, 2017). The improvement in microbial properties will improve the physical and chemical properties of soil (Haruna and Nkongolo, 2015; Nivelle*et al.,* 2016; Summers *et al.,* 2014).

CARBON SEQUESTRATION

Carbon balance is considered as one of serious issues in most parts of the world (Petter *et al.,* 2017). The enhancement of organic carbon in the soil is termed as carbon sequestration. Introduction of cover crops may increase the soil organic carbon up to 0.32 Mg per hectare per year (Poeplau and Don, 2015). Cover crop like ryegrass when incorporated in soil had significantly escalated the soil organic carbon (Poeplau *et al.,* 2015). Sainju *et al.,*(2017) reported that crimson clover as cover crop along with elephant grass greatly influenced the organic carbon of soil from 0.1 to 1 Mg C ha^{-1} $year^{-1}$ that enhanced carbon sequestration. Similarly cover crop like forage radish also had the aptitude for lessening against soil C exhaustion (Wang *et al.,* 2017). Cover crops like *Bromus catharticus* L. and *Vitis vinifera* L. improved soil organic carbon, microbial biomass carbon, β-glucosidase activity and soil CO_2 efflux that leads to carbon sequestration (Peregrina, 2016). The crop like hairy vetch as a cover crop enhanced the microbial population that lead to improve the carbon sequestration (Frasier *et al.,* 2016). In Japan, cover crops like hairy vetch and rye were planted in upland rice and noticed that cover crops expanded the soil organic carbon upto 13.4 and 8.6 Mg ha^{-1} $year^{-1}$ as compared to plots without cover crops (Higashi *et al.,* 2014). Cover crops also trend to decrease the soil pH from 6.7 to 5.7 that eventually increased the soil organic carbon (Mukherjee and Lal, 2015). The cover crops have a great potential to enhance soil organic carbon but data are collected from small plots, not by large area or in the field conditions, where the results may vary (Ladonia *et al.*, 2016). Cover crops also help to maintain C: N ratio in the soil (Verzeaux *et al.*, 2016).

IMPROVE FOOD QUALITY

The environment protection and food that is safe for human health are the two important factors for current agricultural production (Robacer *et al.,* 2016). Plantation of cover crops in some cases enhances the yield of crop, but in certain cases cover decline the yield of crop. Yet improve the quality of food i.e. clover cover crop plantation in wheat improves the protein contents of wheat (Hiltbrunner *et al.,* 2007). In wheat, having no legumes cover crops results in decreased protein content of grain and yield of wheat due to less availability of nitrogen and heavy weed infestation (Amosse *et al.,* 2013). Cover crops plantation especially legumes increased the nitrogen content in plant tissue and root zones of Abaca and improve the yield (Armecin *et al.,* 2005). Cultivation of cover crops declines the yield of grapes but the polyphenols and anthicyanin content % were increased in grape that help to enhance the nutritional value and these compounds help against insects pest (Muscas *et al.,* 2017). Competition of cover crop improves the vine canopy characteristics and leads to improve the berry environment and berry nutritional composition (Giese *et al.,* 2014).

IMPROVE NITROGEN CONTENT IN SOIL

Nitrogen leaching is one of the serious problems in the world. 65-70% reduction of nitrogen leaching was observed in the field where cover crops were planted (Wyland *et al.*, 1996). Nitrification is one of the major reasons caused by N_2O production. Cover crops plantation decreases N_2O emission and lowers the nitrification process (Baggs *et al.,* 1999). Hairy vetch when planted as cover crop in the field results in the accumulation of nitrogen to the extent of 258 kg N ha^{-1} (Campiglia *et al.,* 2010). Legume crops as cover crops provide extra nitrogen in the soil due to nodule formation in their roots. Cover crops like crimson clover and subclover have high impact to increase soil nitrogen. Cover crops also improve carbon and nitrogen ratio in the soil (Kramberger *et al.*, 2009). With a series of experiments, it was concluded that careful completion of cover crops in the fields can lessen the N pollution by applying minimum cost (Roley *et al.*, 2016). One of the reasons of environmental dreadful conditions is due to separation of carbon and nitrogen cycles in the agricultural ecosystems; incorporation of cover crops like legumes in cropping system will reduce cost on nitrogen inputs without any decline in yield of cereal crops like wheat (Bonilla *et al.*, 2017). 10 kg per hectare soil mineral nitrogen was increased in legume cover crops in October month as compared to plots without cover crops (Coombs *et al.*, 2017). The cultivation of winter cover crops in the mountainous areas will lessen the problem of nitrogen leaching in standard cropping system of maize (Feil *et al.*, 1997). Cover crops help to mitigate the nitrogen leaching in the soils and also reduce the input cost on nitrogen fertilizers (Peyrard *et al.,* 2016). Applying input nitrogen fertilizers, helps to increase nitrous oxide N_2O release thus create soil pollution; while this situation could be minimized by cultivation of legume cover crops in the following cropping systems of area (Kim *et al.*, 2017). Sufficient rainfall and proper sowing date are very critical to improve nitrogen uptake and reduce nitrogen leaching in soil (Ritter *et al.,* 1998). In short, cultivation of cover crops is one of the best options of sustainable crop production to nitrogen leaching in the soil and help to maintain crop yield (Sainju *et al.*, 2006).

IMPROVE PHOSPHOROUS CONTENT OF SOIL

Series of experiments emphasize the effects of cover crops on carbon sequestration and reduces the nitrogen losses but some scientists have also explored the potential of cover crops on phosphorus availability. The main losses of phosphorus are due to runoff (Riddle and Bergstrom, 2013) and immobilizations of phosphorus with iron and zinc (Cui *et al.,* 2015). Zhang *et al.* (2017) reported that cover crops reduced the surface runoff upto 32 % as compared to the plot without cover crops and also minimized the phosphorus losses upto 26% as compared to plots without cover crops. Red clover was cultivated as cover crop in Canada to explore its potential to minimize phosphorous losses and it was observed that phosphorus losses were reduced by red clover intercropping (Lozier *et al.,* 2017). The deficiency of phosphorus is mainly due to its binding with minerals and organic matter. Thus, cover crops along with soil microbes increased the rate of phosphorus cycling through plant uptake and with the help of microbial decomposition that contributes to phosphorus mobilization (Landry *et al.,* 2014) and similarly cover crop like *Paspalum notatum* L. are cultivated in guava orchards to improve the phosphorous availability to guava trees (Cui *et al.,* 2015).

MITIGATE GREENHOUSE GASES

Production of greenhouse gases is considered as a major problem in modern agriculture. Greenhouse gases viz.. CO_2, N_2O and CH_4 are the major gases that are produced by agricultural activity (Negasse *et al.,* 2015). 40-60% emission of N_2O is due to agricultural soils (Jarecki *et al.,* 2009). Chinese milk vetch was cultivated between rice fields and it was noticed that 28-61% of methane emission was reduced as compared to rice field having no cover crops (Kim *et al.,* 2012). N_2O emission and leaching of nitrogen were reduced due to planting of rye as cover crop (Jarecki *et al.,* 2009). Plantation of legume cover crops with maize in no tillage soil reduced the CO_2 emission from -971 to -2818 kg CO_2eq ha^{-1} yr^{-1} (Bayer *et al.,* 2016). Incorporation of legumes cover crops and improved cultural practices help to limit the N_2O emission and minimize the global warming (Peyrard *et al.,* 2016; Kim *et al.,* 2017).

DECREASE SOIL EROSION

Erosion is one of the serious hazards leading to soil degradation and loss in fertility status of soil (Farooq *et al.*, 2011). In order to mitigate the soil erosion dilemma, cover crops can play an important role because cover crops provide cover to soil (Meerkerk, 2008). Use of cover crops to prevent soil erosion has been reported by many scientists (Malik *et al.,* 2000; Kaspar *et al.,* 2001; Morgan, 2005). Cover crops cultivation in the soil leads to conservation agriculture where minimum tillage practices takes place thus erosion can be lessening (Horton *et al.*, 2011). Despite reducing weed density and improve N content in soil cover crops also have the ability to conserve soil from erosion (White and Thomas, 1990). Cover crops also decrease 3.5% bulk density of soil with respect to soil having no cover crop (Haruna and Nkongolo, 2015). Planting of cover crops should be done especially on mountainous areas where orchards and grapes plantation take place, so cover crops provide permanent soil cover, thus soil erosion can be reduced (Hermawan and Bomke, 1997; Feil *et al.*, 1997). Although cultivation of cover crops biomass becomes less effective to minimize the soil erosion from water, due to freezing of cover crops at the beginning of winter periods in snow fall areas yet roots of these cover crops still contribute to minimize the soil erosion (Baets *et al.,* 2011). Permanent mono-cropping can cause serious problems like loss in soil fertility, increase run off and soil erosion, with the addition of cover crops, the target of sustainable production within agricultural system can be achieved (Chavarria *et al.*, 2016).

IMPROVE ENVIRONMENT QUALITY

Cover crops mitigate the green gases like CO_2, CH_4, and N_2O (Negassa *et al.,* 2015; Bayer *et al.,* 2016; Kim *et al.,* 2017) that ultimately improve the environmental quality of agricultural communities. Cover crops also minimize the aquatic eutrophication and also improve the nitrogen use efficiency as a decisive pulled point to enhance the environmental performance especially in arable farming areas (Prechsl *et al.,* 2017). APSIM model i.e. Agricultural Production Systems SIMulators (Model) was created to simulate biological and physical processes ocurr in agricultural system, especially this model relates to the ecological and economic conclusions of management practices in the face of climate risk. Model like APSIM was used by scientists to evaluate the impact of cover crops on environment. Model predicted that cover crops had the potential to reduce soil erosion 11-29% along with 34% reduction of N_2O emission (Basche *et al.,* 2016). Cover crops enhance water holding capacity to soil (Igos *et al.,* 2016) that improves the soil biota and leads to sustainable agriculture.

PROSPECTS OF COVER CROPS BY UTILIZING MODEL CALIBRATIONS

A model is a schematic representation of the conception of the system (Sirotenko, 2001). Numerous models are utilized to identify the cover crops in cropping systems and also help to predict the benefits of cover crops (Tixier *et al.,* 2011). Models like SIMBA-CC (Tixier *et al.,* 2011) SIMBA-IC (Ripoche *et al.,* 2012), Conceptual model NDVI (Munoz *et al.,* 2010) and APSIM (Feria *et al.,* 2016) were utilized to predict the efficiency of cover crops against soil erosion and to mitigate greenhouse gases.

Increase Organic matter

Due to increase in carbon and nitrogen ratio in the soil, organic matter of the field can be improved by cultivating cover crops. Cover crops help to improve the microbial activities in the soil, thus organic matter can be increased. Cover crops help to make large soil aggregates, which improve the soil structure, increase water holding capacity of the soil, decrease the bulk density of soil, increase the pores spaces, increase infiltration rate (normal rate 15mm/hour), improve soil tilth, improve soil quality and its properties.

Increase land Use efficiency

By growing cover crops in the field land use efficiency of field can be improved. Cover crops like clovers, chickpea, oat, hairy vetch etc can improve land use efficiency along with cash crop (Banik *et al.*, 2006).

Drawback of cover crops

Despite above illustrated tremendous importance of cover crops and their worth in agricultural system, cover crops have certain negative aspects that are discussed below.

- ✓ For proper growth, cover crops require a lot of water like clovers require water on regular basis (Ingel *et al.*, 1998).
- ✓ Cover crops compete with cash crops for moisture, and nutrients which ultimately decrease the return of cash crops (Newman *et al.*, 2007).
- ✓ Cover crops when compete with main crop for soil resources result into certain stresses like nitrogen stress, water stress for the main crop (Celette and Gary, 2013)
- ✓ If cover crops are grown as unwanted way or irregular pattern, these cover crops are also considered as weeds in strict sense (Ingel *et al.*, 1998).
- ✓ Cover crops also attract pests i.e. if canola is grown between the lines of wheat crop, wheat aphid population will be high.
- ✓ The standardized benefits of cover crops need to be calculated in terms of money to sustainable soil health for long term basis and to the farm as well (Sullivan, 2003).
- ✓ Many scientists pointed that cover crops help to reduce CH_4, still some scientist claimed that cover crops also contribute to CH_4 emission (Pramanik *et al.,* 2014; Hwang *et al.,* 2017), and also enhance N_2O emission (Brozyna *et al.,* 2013).
- ✓ If cover crops are planted in the field, extra seeds are also inter-seeded in the field so the seed cost and its effects on increase N content in the soil and weed suppression should be calculated.
- ✓ Despite countless advantages farmers are still hesitating to grow cover crops in their farming systems due to lack of knowledge about cover crops (Mwangi *et al.*, 2015).

CONCLUSIONS

To protect the environment and produce healthy and safe food are key issue. According to Daily Times, in Pakistan soil erosion is 20% and organic matter is less than 1%. So, cultivation of cover crops helps to minimize the adverse effect of erosion and enhance the organic matter content in soil Cover crops may decline the yields but their plantation are one of the steps that leads to sustainable or conservation agriculture.

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