OPEN ACCESS Freely available online

Journal of Agricultural Science and Food Research

Review Article

Importance of Agronomical and Biological Soil Water Conservation Measures to Enhance Soil Fertility and Reducing Soil Erosion: Review

Yohannes Walie*

Department of Natural Resource Management, Raya University, Addis Ababa, Ethiopia

ABSTRACT

Soil erosion is a serious problem in rural area throughout the world especially in developing countries. Soil water conservation measures play significant importance to protect soil erosion and fertility degradation which leads to enhancing productivity. The objective of this paper was to review importance of agronomical and biological soil water conservation measures to enhance soil fertility and reducing soil erosion. There are different types of biological and agronomical conservation measures such as; row cropping, contour cultivation, multiple cropping, buffer cultivation, mulching, agroforestry and conservation tillage. Based on different published research sources, this review proves each conservation measures have variable performance on soil loss impounding and fertility enhancement. However, researchers agreed up on these conservation measures are so effective in soil erosion hindering and fertility enhancement over non-conserved area and physical soil water conservation measures. Not only decrease running soil from farm land, these structures also improve soil fertility by retain soil organic matter from residue of leaves and branches, develop soil moisture and make gentle or nearly gentle of steep slopes. It is more applicable and effective where arable lands are not extremely steep and fertility improvement is highly required. Therefore, farmers should apply biological soil water conservations measures basically for the purposes of soil fertility enrichment and development.

Keywords: Multiple cropping; Mulching; Buffering; Soil moisture

INTRODUCTION

Over the last half-century, world population doubled while food supply tripled, even as land under cultivation grew by only 12%. Comparatively, the world's highest yields gross output of crops and livestock per hectare of land are found in the developed countries of Asia and America. The reason why those developed countries can achieve the higher growth rates in agricultural productivity, they have built national appropriate systems and stream of new technologies suitable for local farming systems which capable of producing high quantity products qualitatively [1]. Agricultural productivity in developing country has been increasing in a very poor annual growth rate even if there is not uniform way of productivity through such countries. This is due to rapid population increases in developing countries, where the major livelihood income depends upon agricultural practices and rapid soil fertility declining.

As populations grew, soil fertility was gradually depleted by crop-harvest removals, leaching and soil erosion, when farmers were unable to sufficiently compensate these losses by returning nutrients to tire soil *via* crop residues, manures and mineral fertilizers. Bationo conclude that soil-fertility depletion in smallholder farms is the fundamental biophysical root cause of declining per capita food production in Africa and soil fertility replenishment should be considered as an investment in natural resource capital.

Smallholder farmers also cultivate low-potential areas primarily in sub-humid and semiarid areas, where many of the sandy soils are naturally infertile. According to the report by Roland J, et al., there are two basic reasons for the nutrient depletion process, which are; the breakdown of traditional practices and low priority given to the rural sector.

Correspondence to: Yohannes Walie, Department of Natural Resource Management, Raya University, Addis Ababa, Ethiopia; Email: yohanneswalie@gmail.com

Received: 11-Oct-2019, Manuscript No. JBFBP-23-2460; **Editor assigned:** 16-Oct-2019, PreQC No. JBFBP-23-2460 (PQ); **Reviewed:** 30-Oct-2019, QC No. JBFBP-23-2460; **Revised:** 21-Jun-2024, Manuscript No. JBFBP-23-2460 (R); **Published:** 19-Jul-2024, DOI: 10.35248/2593-9173.24.15.175.

Citation: Walie Y (2024) Importance of Agronomical and Biological Soil Water Conservation Measures to Enhance Soil Fertility and Reducing Soil Erosion: Review. J Agri Sci Food Res. 15:175.

Increasing pressures on agricultural land have resulted in much higher nutrient outflows and the subsequent breakdown of many traditional soil-fertility maintenance strategies, such as fallowing land, intercropping cereals with legume crops, mixed crop-livestock farming and opening new lands played a great role for soil fertility reduction. Such strategies have not been replaced by an effective fertilizer supply and distribution system.

The reason behind declining of soil fertility and agricultural productivity is due to poor agronomic practices, droughts, lack of cash for investment and sever soil erosion. Not only household income become diminishes because of soil fertility reduction, but also extends into the community, regional and national scales. Soil nutrient depletion lowers the returns to agricultural investment, which reduces nonfarm incomes at the community level through multiplier effects [2].

Based on Bationo report, about $ 42 billion in income and 6 billion of productive land are lost every year due to land degradation and declining agricultural productivity. African soil mining balances are often negative indicating that farmers mine their soils and about $ 4 billion per year is lost due to nutrient mining.

Global cost estimates of the soil loss by soil erosion are of the order of US $ 400 billion per year. This substantial cost came basically from mismanagement of agricultural systems, such as denied conservation agriculture, disturbance tillage, ignoring crop residues or mulching and cultivate the same crop continuously.

The proper planning of soil and water conservation technologies and its implementation depends on measurements, observations, estimations and perceptions made by different stakeholders like practitioners, technicians, politicians, scientists and development agents. In order to maintain soil erosion and develop soil fertility which again to increase agricultural productivity, applying suitable soil water conservation mechanisms is inevitable decision.

Soil management is concerned with ways of preparing the soil to promote dense vegetation growth and improve its structure so that it is more resistant to erosion. When deciding what conservation measures to employ, preference is always given to agronomic treatment.

Not all soil water conservation measures are effective in different erosion types. Regarding to this, water erosions such as inter-rill/ sheet erosion and rill erosion can be controlled by soil management practices. Engineering structures such as grassed waterways and stream bank reinforcement are usually needed to limit other types of water erosion.

The principle of agronomic and biological soil water conservation measures is to maintain a high vegetative cover, which can serve both production and protection. From biological measures, plant residues build up soil organic matter and thus improve stability of the soil structure and aggregates. Agronomical and biological soil conservation measures are the most effective mechanisms to maintain soil erosion and enhance its fertility and mechanical measures are effective in water conservation aspects.

LITERATURE REVIEW

Role of agronomical and biological soil water conservation measures against soil fertility and erosion

Conserving soil and water directly depends on the management of tillage and cropping systems. Appropriately designed cropping systems enhance soil fertility, reduce soil erosion and improve soil properties. Most organic matter is located on top soil about approximately 50 cm depth such as Phosphors (P) and Potassium (K). Losing top soil leads losing such essential nutrients and again productivity of crops will be decline. Therefore, conserving available soil erosion directly relies on conserving nutrients which are fundamentals for yield maximization [3].

There is a lot of soil water conservation measures which applied based on topography or slop, land use type, erosion kind and easy to applicable. Mostly such conservation measures categorized under mechanical or physical and agronomical or biological. Occasionally, they may be classified as mechanical/ physical (includes; terrace, waterway, check dam, gabion, contour bund), crop management (includes; multiple cropping, intercropping, alley cropping, agroforestry, shifting cultivation, improved fallow, crop rotation, buffering) and soil management (includes; no tillage, minimum tillage, contour cultivation, strip cultivation). However, on this review, we discussed only effectiveness and roles of each agronomical or crop management and soil management measures rather than their category and classification.

Agronomic and biological/vegetative measures create effects both above and below the soil surface. Plants, plant residues and coarse clods (soil aggregates) form an increased surface roughness that in turn enforces a reduction of runoff velocity, accumulation of erode particles, increase infiltration, reduce the effect of rain splash, decreasing the amplitude of the surface temperature, reduce evaporation losses, improve soil fertility and ensure agricultural production.

One way of achieving and maintaining a fertile soil is to apply organic matter. However, to increase the resistance of soil erodibility by building up organic matter may take long term activity. Modifying soil with organic matter improves the cohesiveness of the soil, increases its water retention capacity and promotes a stable aggregate structure. For organic matter remediation of soil, implementation of agronomical or biological soil water conservation measure such as crop management and soil management is incomparable strategy. The basic reason behind motivating to utilize organic fertilizer through vegetation cover, plantation and intercropping is that mineral fertilizers cannot improve the aggregate structure of a soil on their own; they need organic support. The continual use of mineral fertilizers without organic manures may also lead to structural deterioration of the soil and increased erodibility. Agronomic practice improves the soil physical conditions by the maintenance of soil properties (structure, porosity, moisture retention capacity and permeability) and through a combination of maintenance of organic matter with the effects of roots (breaking up of compact layers by roots) [4].

DISCUSSION

Row crops

Row crops refer to crops grown in parallel rows. Reducing space between rows has important implications to soil and water conservation and crop yields. Crops grown in narrow spaced rows provide better protection against raindrop impacts by forming a close canopy. Higher canopy cover or closed canopy cover in narrowly spaced row crops as compared to wide rows reduces evaporation and decreases soil's susceptibility to erosion (Figure 1).

Figure 1: Row crops.

The closed canopy cover rapidly shades the soil surface, reduces soil temperature and weed proliferation although vehicular traffic can be difficult. Row cropping is helpful methods to decline the slope gradient and support terrace development and controlling runoff velocity. Based on Grimes investigation, maize crop grown in alternate row (row cropping) provide better yield than broadcast seeded maize. This is due to row cultivation reduce crop competition over nutrients, moisture and sunlight distribution [5].

Multiple cropping

Multiple cropping is a system where different crops are simultaneously planted on the same field during the same season a year. The method involves either sequential cropping, growing two or more crops a year in sequence or intercropping, growing two or more crops on the same piece of land at the same time. Multiple cropping system provide enormous significance which includes; allows the production of diverse food crops, improves soil fertility and offers better soil erosion control by continuous growing of crops with variable biomass production. On the same author, integrated cropping mechanisms have also reduced disease pressure and use of synthetic fertilizers, herbicides and pesticides by dense planting and intensive management methods. Intercropping systems is one type of multiple cropping, which including different kinds of annual crops planted in alternating rows also reduce soil erosion risk by providing better canopy cover than sole crops.

Based on the report by Morgan, the intercropping of maize with cassava offers the advantages of a two crop canopy, giving a higher interception capacity and reducing the detachment of soil particles by raindrop impact to 35 and 60 per cent of the respective values from cassava and maize alone. On a 6° slope also, mixed maize-cassava reduced annual soil loss to 86 t ha^{-1} compared with 125 t ha^{-1} for cassava as a monoculture. The study by Stoltz and Nadeau, showed that intercropping of maize and faba bean production generate positive yield effects with minimum the risk of nitrogen leakage after harvest. Runoff under sole maize is 67.6% of bare ground, while maize inter-cropped with cow-peas is only 14.3% that of bare ground. This means there is 4.73 times more runoff under maize as a mono-crop than under maize inter-cropped with cow-peas [6].

Contour farming

Contour farming is the practice of tilling, planting and performing all cultural operations following the contour lines of the field slope.

Contour farming is an effective tillage practice for controlling soil erosion and increasing crop yield. It is the practice of tillage, planting and other farming operation performed on the contour of the field slope. Furrow, which is created by contour farming at perpendicular to the predominant field slope, reduces runoff velocity. These furrows retard the runoff velocity, reduce the runoff transport capacity, enhance soil fertility, develope water infiltration, reduce sediment transport and discharge excess runoff at non-eroding velocities (Figure 2).

Figure 2: Contour farming.

This can reduce soil loss from sloping land up to 50% compared with cultivated up-and-down the slope land.

Benefit of contour farming is greatest on moderate slopes (2%-6%) when crops are planted in tilled soil where ridge height is 2-3 inches. However, even with no-till, contour farming can reduce erosion if residue cover is marginal and ridge height is 2 inches or more. In dried areas, contour farming increases crop yield by increasing infiltration and retaining water. In addition, nutrients such as nitrogen and phosphorus in runoff are retained better in contour ridge tillage compared with up and downslope tillage. Farahani, et al. reviewed that soil loss from up and down plowing was 26.1 ton per hectare whereas from contour cultivation practice was reduced to 13.2 ton per hectare. On his reviewed, water loss also reduced from 6.9% of rainfall on down cultivation to 4.7% of rainfall on contour cultivation. Dano shown that contour cultivation can minimize about 28.6% of the average soil loss in relative to farmers' conventional (up-and-down) cultivation practice. This study points out contour farming lost about 3.29 ton/ha/year soils while up and down farming/ cultivation loss 11.5 ton/ha/year soil [7].

Strip cropping

Strip cropping refers to the practice of growing crops in alternate strips of row crops. It is a method of farming used when a slope is too steep or too long, or when other types of farming may not prevent soil erosion. This cropping system is an effective practice to reducing soil erosion because it breaks sloping landscapes in wide segments with diverse vegetative cover which intercepts runoff and promotes water infiltration, thereby reducing runoff and soil erosion. Crops cultured in strips perpendicular to the direction of wind or flood where field orientation is not restricted as a means to reduce the effect of soil erosion. Usually, strip of crops are cultivated or planting with different varieties of erosion tolerant and susceptible alternatively (Figure 3).

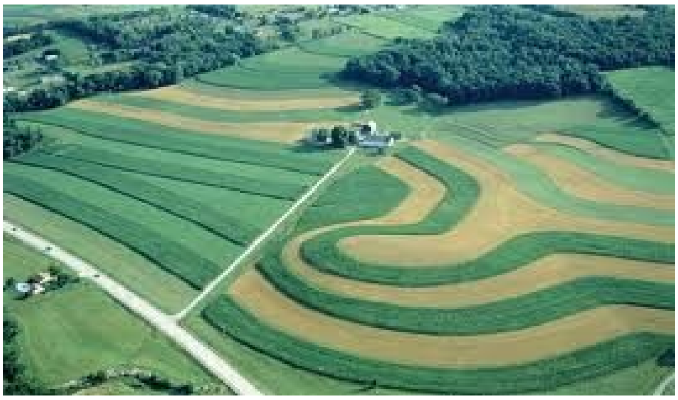

Figure 3: Strip cropping.

The grass strips are about 2 m-4 m wide and the cropped area about 15 m-45 m wide depending on the slope. Width of the strip can be determined by the fallowing formula.

$W=51.2-(2.1 \times S)$, Where: W=strip width (m), S=slope (%)

Strips of 0.5 m and 1.0 m wide reduced soil loss to 36 per cent of than from an unprotected bare plot but a 1.5 m wide strip reduces only a further 18 per cent of soil erosion. When the width of strip increases, the potential of erosion reduction also increases. As other studies revealed that mentioned in the book of Morgan, 1 meter wide strips reduced sediment discharge by 50-60 per cent, 5 m wide strips by 60-90 per cent and 10 m wide strips by 90-99 per cent [8].

Dano reported that 4.5 t/ha/year of soil lost by water erosion from strip cultivated farmlands while 11.5 t/ha/year soil eroded from up and down cultivation farmlands. This implies that strip cultivation/cropping can reduce soil erosion by 39% comparing to conventional tillage such as up and down.

Conservation tillage

Conservational tillage is any system that reduces the number of tillage operations, maintains residue cover on the soil surface and reduces the losses of soil and water relative to conventional tillage. It is a set of innovation technologies including no till and minimum tillage systems such as mulch tillage, strip tillage and ridge tillage. Different studies confirmed that conservation tillage is a suitable measurement to reduce soil erosion. Thus, economical profit obtained from conservation tillage may rise up to 127 Euro ha^{-1} year-^{1} compared to conventional tillage. Tillage is a dynamic process that alters the nature of soil surface and influence detachment, displacement, aggregation and translocation of soil to lower elevations. All studies agree that conservation tillage practices reduce soil losses and increase the amount of residues available for energy production. It is noted that the values of soil losses in conventional tillage varied between 4 to 59.7 t ha^{-1} $year^{-1}$ while conservational tillage between 3.4 to 38.7 t ha^{-1} $year^{-1}$. This shows that conservation tillage practices reduce about 33.2% in average relative to conventional tillage practices. Under conservation tillage soil pH, soil organic matter, soil bulk density, soil organic carbon and total nitrogen is higher than conventional tillage. Soil organic carbon content in topsoil were 23% in conventional and 36% in conservational and total nitrogen content were 14% in conventional and 29% in conservational tillage.

Mulch tillage is a practice where at least 30% of the soil surface remains covered with crop residues after tillage. Tillage under this system is performed in a way that leaves or maintains crop residues on the soil surface. Mulch tillage have fundamental impact in reducing the splash effect of the rain, decreasing the velocity of runoff and hence reducing the amount of soil loss has been demonstrated. Strip tillage is also called partial-width tillage and consists of performing tillage in isolated bands while leaving undisturbed strips throughout the field. By doing so, strip tillage combines the benefits of no-till and tillage. No-till can conserve soil erosion up to 90% relative to conventional tillage due to it ensure soil structure, aggregation and stability which again reduce soil erodibility and it is effective in prohibit sediment transport. No tillage can allow to present excess earth warms which permit to exist high infiltration rate and minimum runoff flow. The report by Mcgregor, et al. also demonstrated that no-till reduced erosion losses, less than 1.57 metric ton/ha (0.70 ton/ac), while soil losses from conventional till were increased, 20.2 metric ton/ha (9.0 ton/ac) [9].

Ridge tillage is a system in which 15 cm to 20 cm high permanent ridges are formed by tillage during the second cultivation or after harvest in preparation for the following year's crop. The ridges are maintained and annually re-formed for growing crops. Crops are planted on the ridge tops, a practice known as ridge planting. This system is designed to reduce costs of tillage, improve crop yields and reduce losses of runoff and soil. Ridge tillage can reduce soil erosion by as much as 50% as compared to conventional tillage (Figure 4).

Figure 4: Ridge tillage.

Buffer cultivation

Buffers are strips or corridors of permanent vegetation which are 5 m-15 m wide used to reduce water and wind erosion (Figure 5).

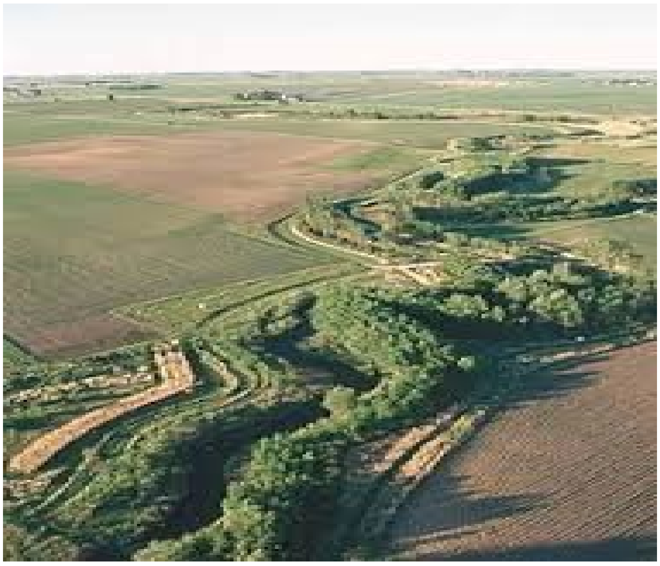

Figure 5: Buffer cultivation.

These conservation buffers are designed to reduce water runoff and wind velocity, filter sediment and remove sediment-borne chemicals. Buffers provide numerous and positive benefits to water quality, agricultural production, wildlife habitat and landscape aesthetics. Buffer strips improve the quality of soil, water and air. Buffers spread the incoming runoff, filter sediment and promote sedimentation. It can also stabilize soil and promote water infiltration through their roots.

Conservation buffers can hold about 70% of sediments and 50% of nutrients, depending on the type of buffer, plant species, management, rainfall intensity and soil slope [10].

The study by Sinore, et al. conducted in Lemo district Ethiopia, revealed that biological soil water conservation measures such as elephant grass and sesbania planting as buffering significantly ($P<0.05$) improved soil chemical properties including soil Cation Exchange Capacity (CEC) and exchangeable bases (Na^+, K^+, Ca^{2+}, Mg2+). This shows that implementing biological soil water conservation species can substantially be contributing to soil fertility improvement because the small rise in soil CEC and exchangeable bases has a big meaning for soil fertility. Buffers may intercept sediment or remove pollutants up to 50 percent from runoff. Another study prove that buffer strips reduced average outflow sediment concentrations by more than 60% (60% to 80%) relative to inflow concentrations. However, the study of Asmussen, et al. revealed that 24.4 m long grassed buffer with a drainage area reduced the suspended sediment concentrations by 98% and 94% for the dry and wet treatments, respectively. The research conducted at Philippines showed that the use of buffer hedgerows and contour cultivation soil loss was reduced from 124 tonne/ha to 40 tonne/ha. On the same study, if crop residues were used as mulch in addition to contour cultivation companion with buffering, soil loss was markedly reduced to 3 tonne/ha.

Agroforestry

Agroforestry is a collective name for a land use system in which woody perennials are integrated with crops and/or animals on the same land management unit. It is an integrated approach of using the interactive benefits from combining trees and shrubs with crops and/or livestock. It combines agricultural and forestry technologies to create more diverse, productive, profitable, healthy and sustainable land-use systems. It is a multi-function system due to the existence of a layer of trees in combination with crops or pasture which are short-term cycle. It is new emerging technology for effective soil and water conservation which comprises a wide range of practices that involve establishing and managing trees intentionally around or within croplands, pasture lands and farm animal grounds with the purpose of controlling soil erosion, restore soil fertility and developing sustainable agricultural production systems. The perennial species such as agroforestry and tree covers act as a surface mulch that replenish soil fertility, retard soil erosion, improve soil moisture and supply soil organic matter [11].

Agricultural cultivation by using agroforestry system can increase soil fertility because of the pumping of nutrients by the trees from the deep soil layers and the recycling of leaves. The deep root system of the trees under soil profile takes nutrients from the deeper soil layers, reducing the loss of these through lixiviation. These nutrients are recycled through the decomposition of leaves, returning to the roots and increasing the efficiency of resource use in the system. However, the improvement of soil nutrients due to the cultivation of area with agroforestry may take several years which is because of leaf of trees taken by farmers for animal fodder and branches removed for fuel wood. In cases of *Acacia albida*, organic matter and nitrogen increases in 50%-100% under the canopy are known together with increased water-holding capacity. Higher soil organic matter and nutrient content found under tree canopies than in adjacent open land. The same study discussed about maize and sorghum in pot samples from soils under trees in northern Nigeria grew 2 to 3 times faster than in soil with no trees.

Magnitude of reductions in soil erosion through agroforestry is region-specific and depends on differences in soil management, climate and vegetation types. The role of agroforestry in reducing soil erosion is widely recognized and acceptable soil water conservation measures. The tree canopy in agroforestry type of cultivation intercepts rain drops, lessening the intensity of its impact on the soil and the tree root system, improves the physical properties of the soil and also facilitates infiltration and increases the capacity of water retention. It can reduce runoff and soil erosion as much as does a no-till system. It might contain soil erosion as much as 100 times in soils with steep slopes of up to 50% relative to non-conserved site. The study of Paningbatan, et al. revealed that alley cropping from agroforestry system with minimum tillage and mulching practiced, soil loss was reduced from 40 tonne/ha to 0.2 tonne/ha. By the same investigation, runoff also reduced by half relatively from non-alley agroforestry cultivation system or method.

Even if agroforestry originally conceived to address problems of water and wind erosion, it now being increasingly used to reduce non-point source water pollution, mitigating global climate through carbon sequestration and reduction of net emissions of greenhouse gases, alleviating poverty and advancing food security.

Mulching

Mulching is a cover or a layer of decaying organic matter on the soil surface by stubbles, plant residues, manure, compost and even stones, is a supplement to the different soil water conservation measures. Mulching is the traditional soil fertility improvement strategies adopted by farmers and provide higher potential when it integrated with agroforestry species. The value of natural mulches in conserving soil and water is well established due to reducing evaporation loss and protect from raindrop impact. Thus un-mulched cultivated land exhibits a low rate of water intake, high rates of runoff and large amounts of soil loss [12].

Stone mulching not only reduces erosion by decreasing rain splash effect and runoff velocity, but also by conserving moisture under the stones. Mulch also minimizes evaporation, a desirable effect in arid areas. The application of mulch on cultivating land can reduces the deterioration of soil by reducing the speed of movement of runoff. It also reduces the soil erosion, limits the weed confrontation and checks the moisture content of the soil. Due to such reason, it is possible to say mulching restores the soil with its physical, chemical and biological properties, as it adds the both micro and macro nutrients. It also contributes towards yield maximizing up to 50%-60% under rain fed conditions. Mulched plots had higher soil moisture content throughout the growing season than the un-mulched plots. Mulching influenced the moisture holding capacity and moisture release characteristics of the soil. Since the un-mulched, plots eroded severely, the loss of the surface soil decreased the moisture holding capacity of the soil. Based on the report by Paningbatan et al., mulching can reduce 60% of runoff. According to William and Emerson, a crop residue which cover of 20% to 30% after planting reduces soil erosion by approximately 50% compared to a bare field. A residue covers of 70% reduces soil erosion more than 90% compared to a bare field (Figure 6).

Figure 6: Mulching.

According to the report by Govindappa, better plant growth and its yield is achieved on mulching plot rather than alone cultivation. He proves that the yield of potato was greater under the straw mulch (27.9%) and also starch content was higher in paddy straw mulch (18.18%).

Shirish, et al. also revealed that mulching can increase yield of papaya by 65%, mango by 45%, banana by 34%, tomato by 37% and cabbage by 39% due to mulching improves soil fertility.

Mulching can also maximize pH level of the soil related to unmulch soil due to high soil moisture content and soil air percentage decreases which leads ammonification process is dominate. By the same author, soil salinity also reduced in case of mulch farming because of it can reduce evaporation which reduces salt collection and water soluble salts may be taken by mulch layers.

Mulching also significantly decrease soil temperature for all the soil depths. In the initial stages of crop growth, temperature differences of as much as 8°C were observed between mulched and unmulched plots at a 5 cm depth. The maximum recorded temperature for un mulched plots were as high as 42°C at a 5 cm depth while mulched plot was 34°C at the same depth of soil.

CONCLUSION

Soil water conservation measures have different performance on different environments such as topography, soil texture, slope and crop cover. Each structure becomes effective and efficient about soil erosion maintenance at specific characteristics of environmental parameters, weather condition and climate condition. From this review, it can be concluding that biological soil water conservation measures such as, row cropping, strip cropping, buffering, multiple/mixed cropping, agroforestry, mulching, conservation tillage and contour cultivation are more preferable methods over physical soil water conservation measures on nearly gentle slopes and not sever steep areas. They are also typically needed for the purposes of soil fertility maximization due to their leaf residues and remnants used as source of organic fertilizer thus develop and modify soil physical and chemical properties.

It is impossible to generalize that one soil conservation measure have fixed capability regarding to controlling erosion, rather vary at different research sites and other enormous parameters which determine its effectiveness.

RECOMMENDATION

Based on this review depending on a lot of published sources, the following recommendations are forwarded;

- Farmers should use biological and agronomical soil water conservation measures where the farmland is not severing steep and soil fertility maximization necessary.
- It is better to adopt zero and minimum tillage over cultivated lands since they are more fertility conservation and saturation mechanisms.

REFERENCES

1. Afshar E, Yarnia M, Bagherzadeh A, Haghighi RS, Mirshekari B. The effects of cropping systems on soil erosion risks and crop productivity using ImpelERO model and GIS in northeast of Iran. Model Earth Syst Environ. 2016;3(2):1-3.
2. Arora K, Mickelson SK, Baker JL. Effectiveness of vegetated buffer strips in reducing pesticide transport in simulated runoff. Trans ASAE. 2003;46(3):635.
3. AsmussenLE, White Jr AW, Hauser EW, Sheridan JM. Reduction of 2, 4D load in surface runoff down a grassed waterway. J Environ Qual. 1977;6(2):159-162.
4. Clark MS, Horwath WR, Shennan C, Scow KM. Changes in soil chemical properties resulting from organic and low-input farming practices. J Agron. 1998;90:662-671.
5. Fuglie KO, Wang SL. Productivity growth in global agriculture shifting to developing countries. Agric Water Manag. 2012;27(4): 1-7.
6. Fulginiti LE, Perrin RK. Agricultural productivity in developing countries. Agric Econ. 1998;19(1):45-51.
7. Grimes RC. Intercropping and alternate row cropping of cotton and maize. East African Agri Fore J. 1963;28(3):161-163.
8. Stoltz E, Nadeau E. Effects of intercropping on yield, weed incidence, forage quality and soil residual N in organically grown forage maize (*Zea mays L.) and faba bean (Vicia faba L.)*. Field Crops Res. 2014;169:21-29.
9. Sinore T, Kissi E, Aticho A. The effects of biological soil conservation practices and community perception toward these practices in the Lemo district of Southern Ethiopia. Int Soil Water Conserv Res. 2018;6(2):123-130.
10. Sharma NK, Singh PN, Tyagi PC, Mohan SC. Effect of leucaena mulch on soil-water use and wheat yield. Agric Water Manag. 1998;35(3):191-200.
11. Paningbatan EP, Ciesiolka CA, Coughlan KJ, Rose CW. Alley cropping for managing soil erosion of hilly lands in the Philippines. Soil Tech. 1995;8(3):193-204.
12. Misebo AM. The role of agronomic practices on soil and water conservation in Ethiopia; implication for climate change adaptation: A review. J Agric Sci. 2018;10(6).