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THE STUBBLE BURNING PROBLEM IN SUSTAINABLE AGRICULTURE

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Abstract

Review paper

Stubble is the short stalks that remain after harvesting a crop such as wheat. The stubble, which makes up soil organic matter and provides nutrients for soil microorganisms, is important for agricultural production. But farmers are supposed that stubble burning provides convenience in tillage results and reduce diseases and pests, which achieve obtaining higher crop yields, and reduce the economic costs. As the result of burning stubble, soil organic matter is decreased, the soil structure is deteriorated, microbiological activity in the soil is regressed, soil moisture is decreased, the biological balance is deteriorated and the risk of erosion is increased. It is vital to use instruments that mix the stubble under the soil so that it does not interfere with the preparation of the seed bed after the harvest. In regions where there is too much stubble, nitrogen fertilizer should be applied to around 1% of the remaining stalk to ensure that the stubble breaks down and decomposes into organic matter.

In this review, the importance of stubble in agricultural production, stubble management, the reasons why farmers burn stubble, the negative effects of stubble burning on the soil fertility and environment, and solution suggestions are covered.

Keywords: *Environmental pollution, stubble, stubble burning, sustainable agriculture.*

1 Introduction

Grains are the most important source of human nutrition all over the world. Grains are mostly the main products produced in Turkey. In Turkey, grains having a wide range of uses for feed and industrial purposes constitute approximately 55% of the total crop production [1]. The stubble is the short stalks that remain after harvesting a crop such as wheat, barley, rye, and oats.

The stubbles of grains are the most important source of organic matter in the soil. The amount of organic matter in Turkey's soil is usually very small, ranging from about 1 to 4% [2]. The soil organic matter can be increased by mixing stubbles into the soil. The effect of organic matter is great in improving the physical, chemical and biological structure of the soil. The organic matter that acts as a food and a stop for soil organisms is involved in many processes such as bonding individual soil particles, ventilating the soil, increasing the water holding capacity of the soil, and the soil being resistant to erosion and drought [3]. Therefore, for crop production, stubble constituting soil organic matter is of great importance [4, 5].

In this study, the effects of stubble on soil productivity, stubble management, producer's reasons for burning stubble, adverse effects of burning stubble on soil, animals, and the environment were all investigated, with an emphasis on the results of burning stubble and solution proposals.

1.1 Effect of Stubble on Soil Productivity

Soils are one of the few natural resources that can't be created and are nearly impossible to replenish. The stubble is a key source of organic matter that has a significant impact on soil fertility.

Microorganisms play a vital part in soil formation by separating and disintegrating plant and animal tissues that fall to the ground. The major sources of soil formation are the decomposition of organic matter and the appearance of organic colloids, as well as the production of new humus compounds [6]. According to many studies, one gram of soil includes millions of bacteria, one kilometer long fungal micelles, thousands of protozoa, and algae cells [6].

With the protection of stubble in the soil, soil organic matter and related microbe activity increase, soil water holding capacity increases, resistance to wind and water erosion increases, and in short, soil fertility increases. Macro and microorganisms in the soil are critical for the natural ecosystem's long-term viability in terms of decomposing organic matter in the soil, converting nutrients back into the soil, and transforming nitrogen (N) in the air into plant-receivable forms [7].

Soil management practices such as increasing soil organic carbon content, reducing soil handling, fertilizing, mixing soil with plant residues, increasing biological diversity of the soil, and covering the soil surface with hays or dried leaves all help to keep carbon (C) in the soil [8]. The carbon (C) content of soil stubble

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is roughly 45 percent by weight, making it a substantial carbon (C) source for the soil. The number of microorganisms in the soil increases and becomes more active as organic carbon is added to the soil. The amount of CO_2 in the soil increases as a result of increased activities, and many organic acids are generated. Increased acidity aids in the solubilization of plant nutrients [9, 10, 5].

Simultaneously, soil organic matter ensures that soil particles are held together and aggregate stability is established. This is necessary for soil ventilation, increased water holding capacity, and the ability to hold nutrients. In dry seasons, stubble soils retain moisture due to the abundant organic matter in their structure and prevent yield loss by giving the necessary water to the plants growing on them. [11, 12].

Plant residues shield the soil from the direct impact of rain drops in stubble-covered agriculture, preventing the soil from being slapped and drifted. The benefits of stubble-covered agriculture include rainwater absorption, the establishment of a cool and wet soil environment, the reduction of evaporation, the increase of humus, and, as a result, the protection and productivity of the soil [11].

1.2 Negative Effects of Burning Stubbles on Soil

In Turkey, grain agriculture (wheat, barley, oats) was made in 15.723 hectares of land in 2015 [13]. So, huge amounts of stubbles are produced. Depending on the shape height of the wheat, it is reported that on average 3500 kg / ha is burned together with stubble and on average 1000 kg / ha is burned on average, depending on the shape height of the stubble. In general, it can be said that on average 1500-2000 kg / ha stalk, straw, herb, herbal material burned with wheat stubble and stalks which are burnt. If it is assumed that 30% of the total area allocated for grain farming is burned, it can be said that about 5.5-7.4 million tons of stubble are burned without organic matter [14, 4, 15]. When considering the effect of soil organic matter on the physical structure and especially the vitality of the soil, stubble burning is regarded as a considerable loss for soil fertility. Incorrect and unconscious use of agricultural land tends to tire and reduce soil`s productivity. Stubble burning is considered as a wrong land use [7].

As a result of burning down the stubble on the soil, the soil loses its vitality for a certain period of time, the soil structure deteriorates, the soil fertility decreases and the biological equilibrium are affected negatively. Some plant nutrients found in stubble are transformed into oxides, which plants cannot use. These disrupt the physical, chemical and biological properties of the soil. The burning of stubble also promotes soil erosion and affects soil moisture and temperature values. 63% of the land in Turkey is exposed to very severe and powerful erosion [16].

During stubble burning, high temperature (80 ^{o}C) occurs at the top of the soil for a while. The occurring high temperature leads to the disappearance of the microorganisms in the soil and thus to the deterioration of the harmful-beneficial balance [5]. *Trissolcusspp.* species, which provide a natural biological struggle by leaving their eggs in the eggs of the sunn pests that significantly reduce the quality of the wheat product, disappear with stubble burning. It is known that the bugs, which are useful in many biological struggles that survive on field borders, road edges, river edges, bushes life, are killed during stubble fires [11, 17].

At the same time, it has been reported that stubble burning causes decline in carbon dioxide release to the ground, which is caused largely by the reduction in the lives of microorganisms living at a depth of 0-3 cm [17].

In short, as a result of stubble burning, large changes occur in the flora and fauna of the soil.

1.3 Use of Stubble Areas in Livestock

Coarse feed production is gained when grain production is less than predicted, and the utilization of agriculture leftovers in animal feed acts as a form of herbal production insurance for animal husbandry [18]. Natural meadow and pasture lands, as well as feed plant farms, provide high-quality coarse feeds. Damage is unavoidable, however, because the grassland and pasture regions are grazed with timeless, unconscious, and more animals than the capacity allows. As a result, breeders typically supplement coarse feed deficiencies with stubble resides; concentrate feeds, and low-nutrient-value stem and straw [19].

Stubble benefits 80.5 percent of small cow breeding operations in the GAP region. Businesses benefiting from stubble in the provinces of Diyarbakır, Şanlıurfa, Gaziantep, and Adıyaman accounted for 67.1 percent, 92.1 percent, 83.7 percent, and 75.5 percent, respectively. In order to reap the benefits of stubble, grain fields in the provinces of Şanlıurfa and Gaziantep are evaluated by spreading as much as possible at the start of the winter. It has been claimed that stubble is generally used for 6 months in these two provinces, although it can be prolonged to 9 months if the weather is favourable during the winter months. Stubble is an extremely important feed source in the provinces where the research is conducted, and it has been discovered that Şanlıurfa, particularly Gaziantep and Diyarbakır provinces, is mostly utilized in places where there are no or insufficient meadow areas [20].

Sheep can be economically cultivated throughout pregnancy and lactation by grazing on wheat stubbles during the summer (December-April) if the increased protein and energy needs are satisfied by paying attention to the optimum settlement density [21]. Stubble and pasture grazing is one of the feeding patterns utilized in turkey breeding in Turkey. The turkey fowl supplied growth feed during the first 8-12 weeks are grown by grazing in these places where the stubble and pasture possibilities are sufficient [22, 23].

1.4 Negative Effects of Stubble Burning on Animals

Stubble fields are employed primarily to meet coarse feed requirements in small cattle breeding, resulting in economic gain. However, when the stubble is burned, the economic gain that can be obtained is reduced to ashes.

One of the biggest problems that animals can experience is the deterioration of their habitat. Many wild animals (rabbits, birds, foxes, etc.) are losing their

forests and living spaces, and even die with stubble burning and forest fires [4, 5, 7, 24, 25, 26]. It has been determined that the burning of stubble in the Kızılırmak valley completely destroyed the nutrients of the birds that feed on agricultural land in winter [27]. In the Kavak Delta, in a locus of spotted tortoise *(Emysorbicularis)*, indicated to be in close threat under the IUCN criteria, 42 samples of them were reported to be killed due to spread of stubble fire in a 12789 m^2 area [28].

1.5 Negative Effects of Burning Stubbles on the Environment

The air is polluted by stubble fires. At the same time, traffic accidents occur because of the smokes from stubble fires block the view on land roads. Stubble fires can cause burning of forests and residential areas.

During the burning of the herbal material, some airborne particles, such as CO, NO_2, N_2O, O_3, CH_4, benzene and PAH_5 (Polycyclic aromatic hydrocarbons), are mixed into the air as a result of the complete ignition of the organic matter [16, 29, 30]. Contamination of the air that people, plants and animals breathe brings with it many health problems.

Stubble burning is a real environmental problem that is considered to be one of the agricultural activities that cause the release of greenhouse gases, which are seen as the cause of global warming [5, 7, 31, 32]. Global warming is triggered by stubble burning, which releases more carbon dioxide into the atmosphere [33].

Stubble fires sometimes burn live or inanimate fences, fruit gardens, not harvested crops in neighboring fields, and telephone poles on the field boundaries. Burned stubble causes the forests and residential areas to burn with the effect of the wind, rising smoke occasionally obstructing sight on the highways and causing traffic accidents.

In the areas of the most sensitive vegetation cover of the Salt Lake ecosystem, fires that are emerged by stubble burning damage the natural habitat and especially the areas formed by local endemics are severely damaged [34].

2 Stubble Management

All procedures altering the quantity of plant growth left on the soil surface are included in Stubble management [35]. In studies on the management of the residual stubble after grain harvesting, it has been discovered that there are five most regularly utilized ways. These are the following:

1. Spreading the stubble on the soil surface,
2. Making hays out of stubble,
3. Making bales out of stubble,
4. Burying stubble in the soil,
5. Burning stubble.

Stubble dissolving and dispersing systems mounted to the back of the harvester are required to disseminate the stubble to the soil surface. To turn the stubbles into hay, you'll need a hay producing machine. In recent years, simultaneous working hay production systems with harvesters attached to the harvester's back have also been deployed. To make the stubble bales, you'll need a lot of time and effort. If you're replanting just after harvest, you'll need to gather the stubble using a bale machine and then plant it with a machine that plants directly on the stubble [36]. Plows are essential to allow the top soil to be tilted and processed in order for the soil to mingle under the ground and bury the stubble. However, sufficient time and humidity are required to break down the buried underground stubble and convert it to a valuable organic matter for the soil. When plantation happens under these conditions, plant residue makes the use of a planting equipment problematic [37, 32]. The burning of stubble is another option for stubble management. Burning stubble, on the other hand, has detrimental consequences for both the environment and agricultural production.

Alternative tillage methods for stubble management can be listed as follows [7].

a) Use of chisels instead of plows, (amount of plants residue in the soil: 50-70%) [35].
b) Use of disc harrow-cultivator (amount of plants residue in the soil: 40-80% for disc harrow, 30-80 for cultivator) [35]
c) Stripe tillage, (amount of plants residue in the soil: 60-75%) [35].
d) Back tillage, plantation to back (amount of plants residue in the soil: 30-50%) [38].
e) Direct plantation to stubble (most of the stubble is on the soil surface since no tillage is done)

When tillage is reduced, the soil tightness, workforce and fuel consumption of the processing tools will also decrease.

Despite its disadvantageous, the most appropriate method for stubble management seems to be direct plantation to stubble for the healthy future of the soil.

3 Causes of Stubble Burn by Producers

Stubble burning is promoted for a variety of reasons, including easy and quick removal of stubble in the soil, convenient tillage, time savings for second planting, minimizing plantation problems with driller in zero-tillage agriculture, permanent solution to wild grass and seeds, and preventing herbal diseases by eliminating harmful bugs' eggs and larva [4, 5, 15, 32, 39, 40].

However, in humid and cold climates, it is more difficult to prepare fields for the next planting season since the decomposition of plant leftovers in the soil is slower and takes longer.

As a result, farmers in cold and humid climates choose to burn stubble [4, 5, 15, 32, 39].

3.1 Awareness Levels of Producer on Stubble Burning

According to a study conducted by producers to determine stubble burning and awareness levels, 51% of producers stated that stubble should not be burned due to the harm to the living and 11% stated that stubble should not be burned due to the harm to the soil, and only 13% of producers burn stubble. Almost all of the producers in

this study who had their opinions and remarks on the effects of stubble burning were of the opinion that burning stubble was bad (97.67 %).

According to the producers, the most substantial damage (75.58%) caused by the stubble fires was discovered in nature, while the economic loss was discovered to be loss of efficiency (71%). When asked about the producers' thoughts on the stubble burning penalty, 97.67% said they were aware of the penalty and 6.98% said they had been penalized [32]. The Environment Law No. 2872, as well as the corresponding provisions of Law No. 5491 and Forest Law No. 6831 modifying this law [41, 42], imposes penalties on individuals who violate the stubble burning laws. Although most farmers observe this regulation, there are still some farmers who burn stubbles. The location of the burning stubble, however, remains unknown [13].

According to a study done for environmental engineer candidates to apply their environmental knowledge to daily life, 89% of engineer candidates knew about the dangers of burning stubble and cases of burning stubble, and 100% of them showed positive behaviors.

As a result, it is believed that the engineer candidates are aware of environmental issues in the city where they reside and in the country where they live, and that this awareness is a result of their vocational education [43]. Another study in Tokat province found that 49.02% of farmers had a moderate degree of environmental consciousness, 27.45% of farmers had a low level of environmental awareness, and 23.53% of farmers had a high level of environmental awareness [44].

In another study, 71% of farmers said they prefer to mix the stubble into the soil rather than burn it, and when asked what method they prefer, 57.38% said they want to mix the stubble into the soil. Some farmers have reported that they manufacture hay and bales out of the stubble. None of the producers also said that they did not obtain alternative approach information from a consultant or agency [32].

4 Results

Remaining plant wastes are burned unconsciously in many parts of Turkey, especially after wheat harvest. The stubble should not be burned for any reason in order to boost the productivity of agricultural land, protect the life of the soil, raise the amount of organic matter in the soil, make the soil more resistant to erosion, and obtain more crops per unit area.

With stubble fires, animals' grazing areas are burned, fires spread to unharvested agricultural land, macro and micro living beings in the soil are killed, soil organic matter is burned, nutrient substances for plants in the soil are reduced, soil water capacity is reduced, water and wind erosion are increased, ecologic balance is disrupted with forest fires, and drinking water sources are contaminated. All scientific research on the subject concludes that burning stubble is an unintentional act committed without regard for the future. As a result, it has been determined that both farmers and all professions working in agricultural areas should be aware of the problem of stubble burning and provide training to address it.

5 Suggestions

Instead of burning stubble, alternative stubble management strategies should be organized for farmers, with a focus on the importance of this matter, so that the soil's biological, chemical, and physical structures, as well as the environment’s natural equilibrium, are conserved. It is anticipated that conducting practical research that would enhance awareness and knowledge levels by connected institutions would be advantageous in disseminating alternative ways in trainings.

It is vital to use instruments that mix the stubble under the soil so that it does not interfere with the preparation of the seed bed after the harvest. Harvesting should be done with a harvester close to the soil's surface. Following the wheat harvest, the second crop, corn, soybean, and sunflower cultivation, should be encouraged to employ direct sowing methods.

In regions where there is too much stubble, nitrogen fertilizer should be applied to around 1% of the remaining stalk to ensure that the stubble breaks down and decomposes into organic matter. This and other technical advantages should be passed on to farmers in the next training programs, and they should be led to stubble management approaches that are more effective, cost-efficient, simple, and helpful than stubble burning. In order to attain these goals, producers must be provided with technical assistance as well as training. Incentives and grant programs should be provided to producers in order to prevent a shortage of technical equipment, equipment, and machinery that will be required to put all of these recommendations into action. In the case of wild plants and insects, pesticides are recommended instead of stubble burning [11].

The Ministry of Environment and Forestry and the Ministry of Food, Agriculture, and Livestock have created recommendations and fines for stubble burning, which have greatly aided the fight against stubble fires. However, the number of trainings required to raise producer awareness of the negative effects of stubble burning on agricultural production should be increased and maintained.

Declaration of Competing Interest

The author declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Ethics committee approval is not required.

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