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Overcoming barriers to soil carbon sequestration: Constraints and suggestions from sugarcane growers

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Abstract

The current study was carried out to identify the various constraints faced and suggestions given by Sugarcane growers following soil carbon sequestration practices. Kolhapur, Pune, Ahilyanagar and Satara districts from Western Maharashtra were purposefully selected, as these districts are crucial areas for Sugarcane crops. Data was gathered through a structured interview schedule and analysed using frequency and percentage. The findings revealed that more than three fourth 78.43 per cent of the Sugarcane growers faced insufficient availability of climate resilient Sugarcane varieties. Followed by limited potential for agroforestry due to poor yields and shortage of organic input with 57.81 per cent and the demand for Sugarcane in the market leads to monocropping with 50.93 per cent. Majority 90.93 per cent of them suggested organizing awareness programs to educate Sugarcane growers about environmental changes in ecosystems. Followed by creating awareness about the impact of increased CO₂ concentrations on crops and climate with 84.37 per cent and organizing an awareness campaign on the adverse effects of burning Sugarcane trash on the ecosystem with 81.87 per cent. The study concluded that Government should recognize Sugarcane as a valuable source for climate change mitigation. Allocate funding for research on Sugarcane's environmental in addition to economic benefits.

Keywords: Climate change, soil carbon sequestration, sugarcane growers, constraints, suggestions

1. Introduction

Climate crisis and rising temperatures acts as a serious threat to life on the earth. Changing climate is affecting India in a big way and leading serious-erratic monsoon, rise in sea level, change in availability of fresh water, floods, droughts, heat waves and increased concentration of various Greenhouse Gases (GHGs). India's surface air temperature has elevated by about 0.7°C during 1901 to 2018. The sea surface temperature in the Indian Ocean has increased by about 01°C during 1951 to 2015 (Raghavan *et al.* 2020) [7].

The Earth's atmosphere consists of carbon dioxide (CO₂) and other greenhouse gases including methane (CH₄) and nitrous oxide (N₂O). Human activities, including the fossil fuel burning, cement and chemical production, deforestation and agricultural activities, emit Greenhouse Gases (GHGs) such as, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases (F-gases) to the atmosphere (NASEM, 2025). Different agricultural activities such as conversion of forest for agricultural use, crop residues left on the field, inorganic fertilizer use, livestock production, manure management and irrigation are significant sources of agricultural greenhouse gas emissions (Li *et al.* 2025) [12].

The process of burning of farm residues is one of the key sources of greenhouse gas emissions. Biomass burning, including crop residue burning and forest fires, contributes to about 37.00 per cent of global black carbon emissions, intensifying climate change (Bond *et al.* 2013) [12].

Soil carbon sequestration

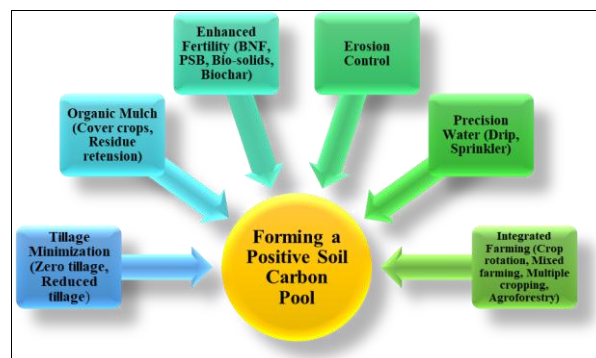
The process in which the carbon dioxide (CO₂) is taken out from the atmosphere and stored in the soil carbon pool is known as soil carbon sequestration. In this process, the atmospheric carbon dioxide is sequestered into soil via crop residues and other organic solids in such a way that it will not immediately remit. Agricultural soils are substantial carbon sinks, offering significant potential for increased carbon storage. Using the recommended package of practices, agricultural soils have the potential to sequester 6 to 7 Tg/yr (Srinivasarao, 2018) [19]. Carbon storage in soil simultaneously improves soil fertility and reduces the consequences of global warming. Therefore, boosting soil carbon storage has emerged as a core strategy for mitigating climate change, supporting long-term agricultural productivity (Srinivasarao *et al.* 2009) [20].

Carbon sequestration in Sugarcane crop

Sugarcane is among the crops capable to cope up with elevating carbon dioxide (CO₂) levels due to its inherent advantages. Key inherent advantages in terms of growing carbon dioxide (CO₂) concentrations in the atmosphere consist of a significantly low carbon dioxide compensation point (rate of photosynthesis is equal to rate of respiration) ranging between 0 to 10 ppm and unique ability to sequester carbon comprised of phytoliths or plant stone. Also, the carbon storing capacity of 181 kg C sequestered/ha/year (Bhatt *et al.* 2023) ^[1]. Plant stones are grains of silica in plant leaves. Specifically, grass-dominated pastures and crops like sugarcane and wheat. Throughout the growth of plant, a small fraction of organic carbon gets trapped inside the microscopic silica grains. Regardless of whether the crop dies, is burned or harvested; the carbon entrapped within the plant stone exhibit high resistance to decomposition. Thus, in contrast to most plant matter, that decomposes easily and releases carbon dioxide (CO₂) back into the atmosphere, the carbon present in plant stone effectively removes carbon dioxide (CO₂) from the atmosphere (Jeffrey, 2007) ^[6].

Soil carbon sequestration management practices

Various agronomic management options used to enhance soil organic matter content. It may reduce or even overturn the loss of carbon from agricultural fields. Soil organic carbon depends on adoption of these practices.



2. Methodology

The research design used for the study was ex-post facto. The study was carried out in four districts of Maharashtra State viz., Kolhapur, Pune, Ahilyanagar and Satara. These districts were chosen on the basis of highest sugarcane production. Total 320 respondents were selected as a sample. The data were gathered through a structured and pre-tested interview schedule by personal interview method. The variables included personal, socio economic, communicational and psychological characteristics as independent variables, while awareness and perception of sugarcane growers towards soil carbon sequestration were considered as dependent variables. The data gathered were classified and analysed using frequency, percentage, rank, mean, standard deviation, Karl Pearsons correlation coefficient and multiple regression.



2.1 Constraints faced by sugarcane growers following soil carbon sequestration

Sugarcane growers were asked whether they faced any difficulties related to soil carbon sequestration management practices in sugarcane crop. The constraints experienced by the sugarcane growers were identified and recorded accordingly. A total score for each constraint was calculated and expressed in terms of frequency, percentage and rank to facilitate proper analysis and interpretation. This helped in drawing meaningful inferences regarding the major problems encountered by the sugarcane growers following soil carbon sequestration.

2.2 Suggestions made by sugarcane growers following soil carbon sequestration

Suggestions were obtained from the sugarcane growers to overcome the problems faced by them in following soil

carbon sequestration management practices in sugarcane crop. The sugarcane growers were encouraged to share their practical opinions and recommendations based on their experience. The suggestions provided by them were grouped according to the nature of constraints faced by them and were systematically organized. These were then presented in terms of frequency, percentage and rank to facilitate analysis and to draw meaningful inferences for the study.

3. Results and Discussion

The findings of the study in addition to relevant discussion given below.

3.1 Constraints faced by sugarcane growers following soil carbon sequestration

Constraints refers to conditions or factors which hinder or

limit an individual's activities. In this research, it was defined as the problems and difficulties experienced by the Sugarcane growers while following soil carbon sequestration. Table No. 1 shows the constraints categorized

into five groups: technical constraints, situational constraints, financial constraints, extension constraints and supply and service constraints.

Table 1: Constraints faced by Sugarcane growers while following soil carbon sequestration

Sr. No.	Constraints	Frequency	Percentage	Rank
A.	Technical constraints			
1.	Insufficient availability of climate resilient Sugarcane varieties	251	78.43	I
2.	Limited potential for agroforestry	185	57.81	II
3.	The demand for Sugarcane in the market leads to monocropping	163	50.93	III
B.	Situational constraints			
4.	Limited awareness leads to Sugarcane trash burning	196	61.25	I
5.	Fragmented land holdings limit agroforestry adoption	193	60.31	II
C.	Financial constraints			
6.	Limited awareness about carbon credit	268	83.75	I
D.	Extension constraints			
7.	Limited awareness of effective soil carbon sequestration management practices	306	95.62	I
8.	Limited awareness of the negative effects of agricultural carbon emissions	287	89.68	II
9.	Absence of government led awareness campaigns on soil carbon sequestration	273	85.31	III
10.	Inadequate technical guidance on soil carbon sequestration from extension services	235	73.43	IV
E.	Supply and services			
11.	High cost of agricultural inputs including organic fertilizers	218	68.12	I
12.	Inadequate access to timely labour and other agricultural inputs	169	52.81	II

In case of technical constraints, it was noted from Table No. 1 that, more than three fourth 78.43 per cent of the Sugarcane growers faced insufficient availability of climate resilient Sugarcane varieties which ranked I. The possible reasons might include pest and disease outbreak, poor quality seeds, low yield due to natural hazards like drought and high temperature affecting the development of climate resilient varieties (Zhao *et al.* 2015) ^[24]. Developing climate resilient crops through research and biotechnology takes time and money. Also, for developing climate resilient varieties farmers need proper education on how to grow and manage climate resilient crops (Dhilani, 2021) ^[4]. Following closely at II, limited potential for agroforestry, scoring 57.81 per cent. Contributing reasons could be poor technical knowledge and inadequate awareness regarding the practice of agroforestry keeps the farmers away from its efficient implementation and maintenance. Inadequate extension services and poor training packages further widens the gap, hampering the adaptation of small-scale farmers to conventional farming to adopt integrated agroforestry measures. Also, the availability of quality planting material, correct agroforestry species and finance remains low in much of the landscapes, which otherwise limits agroforestry scaling (Kuldeep, 2025) ^[8]. The demand for Sugarcane in the market leads to monocropping, earning a ranked of III with 50.93 per cent. The likely factors are the sugarcane monocropping is highly profitable to farmers and sugar industry, as it reduces the cost of production by 30 to 40 per cent (Nivedita *et al.* 2021) ^[15]. Also, sugarcane market in India is becoming monopsonic with certain sugar mills having a significant market share. This has led to farmers being limited to selling their sugarcane only to these designed mills, which can lead to monocropping practices as they have no options for selling their produce (Lavanya *et al.* 2025) ^[11].

With regards to situational constraints, it was found that, majority 61.25 per cent of the Sugarcane growers faced limited awareness leads to Sugarcane trash burning with I

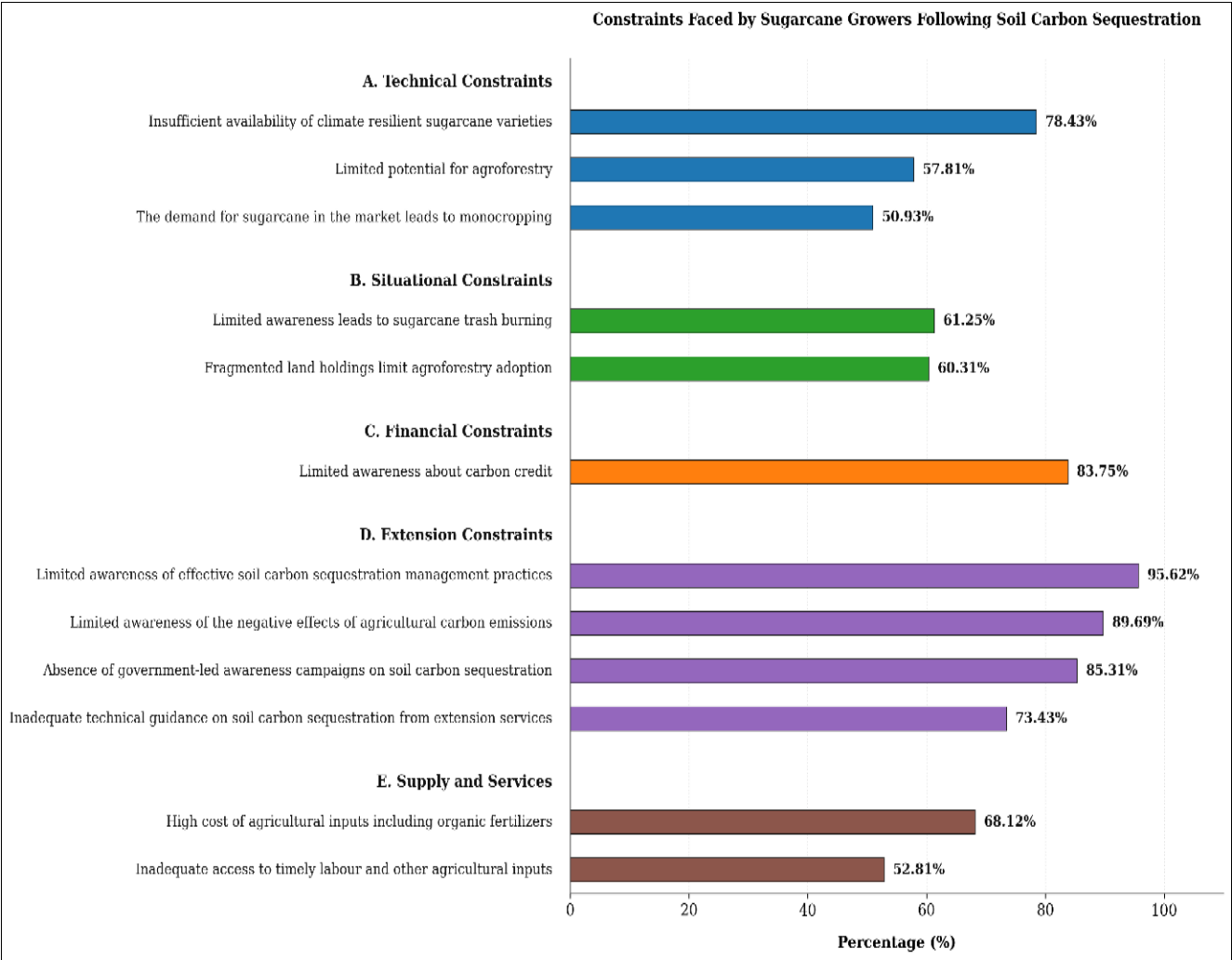
ranking. The key factors responsible for sugarcane trash burning include limited labour availability, financial constraints, lack of awareness and tight crop schedules (Ravish *et al.* 2026) ^[17]. Also, farmers aware of the ill effects of crop residue burning, they still used to burn the residue because there is lack of awareness about the subsidies available and crop residue management technologies (Kungumaselvan *et al.* 2024) ^[9]. Following closely at II, fragmented land holdings limit agroforestry adoption, with percentage of 60.31 per cent. The acceptability and viability of agroforestry are dependent on and fragmentation (Rajeev *et al.* 2023). High population growth acts as a primary driver of this process, which causes severe forest degradation and increasing pressure on land resources. Thus, this resulting land fragmentation poses a crucial challenge to the adoption of agroforestry (Tranchina *et al.* 2024) ^[22].

Limited awareness about carbon credit was the only financial constraint faced by majority 83.75 per cent of the Sugarcane growers. The possible reasons could be lack of financial incentives for the adoption of carbon capture technologies (Van Hoof, 2023) ^[23]. Low digital literacy, hindering the use of monitoring tools and precision agriculture (Ruiz *et al.* 2020) ^[18].

With respect to extension constraints, it was found that limited awareness of effective soil carbon sequestration management practices held the top position, with a ranking of I with 95.62 per cent. Some of the possible reasons are insufficient agricultural extension support to advice on sustainable practices (Jassim *et al.* 2022) ^[3]. Lack of technical knowledge among farmers to identify effective management strategies (Piscitelli *et al.* 2024) ^[10]. Following closely at II, was the limited awareness of the negative effects of agricultural carbon emissions, scoring 89.68 per cent. Possible reasons include lack of knowledge about greenhouse gases emissions from agriculture. Then agriculture is often perceived as natural process, it may lead to misconception that farming emissions are not harmful.

Another possible reason might be the cultural resistance to change and adherence to traditional farming practices (McDonald *et al.* 2021) ^[13]. Ranked III with 85.31 per cent of them faced absence of government led awareness campaigns on soil carbon sequestration. Inadequate technical guidance on soil carbon sequestration from extension services earned a ranking of IV with 73.43 per cent. Potential factors might involve there is limited data on local soil information, use and management. No uniform standards for measuring, reporting and monitoring carbon changes (FAO, 2020) ^[15]. When it comes to supply and services related constraints it

was observed that, high cost of agricultural inputs including organic fertilizers, securing a top ranking of I with 68.12 per cent while inadequate access to timely labour and other agricultural inputs, ranked II with 52.81 per cent. Possible explanations include high cost of agricultural inputs like organic fertilizers, fuels and seeds negatively impact soil carbon sequestration by limiting the adoption of regenerative practices; forcing farmers to prioritize immediate yields over long-term soil health. Also, higher wage rates demanded by labourers limits timely availability of labour for practicing soil carbon sequestration (Suresh, 2017) ^[21].



3.2 Suggestions given by Sugarcane growers to overcome the constraints faced while following the soil carbon sequestration

In Table No. 2, we explore the insightful suggestions brought forward by Sugarcane growers. These suggestions form a crucial aspect of investigation, shedding light on potential strategies to overcome constraints identified. It was indicated from the Table No. 2 that, organizing awareness programs to educate Sugarcane growers about environmental changes in ecosystems, secured the top rank with 90.93 per cent. Ranked at the II position, creating

awareness about the impact of increased CO₂ concentrations on crops and climate, earned a score of 84.37 per cent. At III, organizing an awareness campaign on the adverse effects of burning Sugarcane trash on the ecosystem, received a score of 81.87 per cent. Conducting method demonstrations and result demonstrations on Sugarcane trash management was suggested as crucial obtaining a ranking of IV with 80.62 per cent, followed by conducting soil testing before cropping season, ranked V with 75.93 per cent.

Table 2: Suggestions given by Sugarcane growers to overcome the constraints faced while following the soil carbon sequestration

Sr. No.	Suggestions	Frequency	Percentage	Rank
1.	Organize awareness programs to educate Sugarcane growers about environmental changes in ecosystems	291	90.93	I
2.	Create awareness about the impact of increased CO ₂ concentrations on crops and climate	270	84.37	II
3.	Organize an awareness campaign on the adverse effects of burning Sugarcane trash on the ecosystem	262	81.87	III
4.	Conduct method demonstrations and result demonstrations on Sugarcane trash management	258	80.62	IV
5.	Conducting soil testing before cropping season	243	75.93	V
6.	Provide increased subsidies for sustainable agricultural practices, including organic farming and agroforestry	237	74.06	VI
7.	Ensure regular technical guidance from extension services on soil carbon sequestration	225	70.31	VII
8.	Increase subsidies for water conservation practices, such as micro-irrigation system	213	66.56	VIII
9.	Ensuring timely availability of agricultural inputs such as organic fertilizers	205	64.06	IX
10.	Implementing agroforestry group farming to increase the adoption soil carbon sequestration practices among Sugarcane growers	191	59.68	X
11.	Promote the adoption of intercropping in Sugarcane cultivation	187	58.43	XI

It was also observed from Table No. 2 that, provide increased subsidies for sustainable agricultural practices, including organic farming and agroforestry, securing ranked VI with 74.06 per cent. Ensure regular technical guidance from extension services on soil carbon sequestration, obtaining a ranking of VII with 70.31 per cent. Ranked at VIII, increase subsidies for water conservation practices, such as micro irrigation system, earned a score of 66.56 per cent. Ensuring timely availability of agricultural inputs such as organic fertilizers, secured a rank IX with 64.06 per cent. Implementing agroforestry group farming to increase the adoption soil carbon sequestration practices among Sugarcane growers, obtained a rank X with 59.68 per cent. Finally, at XI position, promoting the adoption of intercropping in Sugarcane cultivation, scored 58.43 per cent.

4. Conclusion

The major constraints were reported regarding insufficient availability of climate resilient sugarcane varieties, limited potential for agroforestry due to poor yields and shortage of organic input, the demand for sugarcane in the market leads to monocropping, limited awareness leads to sugarcane trash burning, fragmented land holdings limit agroforestry adoption, lack of financial support such as subsidies and credits for soil carbon sequestration, unawareness of effective soil carbon sequestration management practices, unawareness of the negative effects of agricultural carbon emissions, absence of government led awareness campaigns on soil carbon sequestration, inadequate technical guidance on soil carbon sequestration from extension services, high cost of agricultural inputs including organic fertilizers and inadequate access to timely labour and other agricultural inputs.

5. Implications

The scarcity of climate resilient sugarcane varieties found as major constraint encountered by sugarcane growers while following soil carbon sequestration. This highlights the need for breeding programs, genetic research and participatory plant breeding by scientists from state agricultural universities. It is important for government to raise awareness about greenhouse gases emissions from various agricultural activities and soil carbon sequestration practices and different schemes related to climate change mitigation, using appropriate communication pathways that are

available to sugarcane growers. Government should recognize Sugarcane as a valuable source for climate change mitigation. Allocate funding for research on Sugarcane's environmental in addition to economic benefits.

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