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**COMMENTARY**

**Essential oil bearing aromatic plants: Their potential for sequestering carbon in marginal soils of India**

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**Abstract**

Continuous rise in the atmospheric CO2 concentration upshots the genesis of cata-clysmic planetary problems such as global warming and climate change. Another critical issue which is environmentally challenging is land degradation. When pro-ductive land is poorly managed, it turns to marginal land. And further degradation of marginal land ends up to being unproductive land. On the Contrary, considerable part of depleted soil C pool can be restored through the adoption of conservation ag-ricultural practices, unproductive land could be converted to marginal land and by its further restoration, into productive land. Aromatic plants can sustain various adverse conditions prevailing on the marginal lands. Aromatic plants require low input but the output is quite high due to the production of highvalue essential oil. The pivotal perspective of utilization of marginal lands of India for the production of aromatic plants would explore factors such as land availability, aromatic plants adaptability, C sequestration potential and economic feasibility. India is the largest exporter of essential oils and produces huge amount of aromatic spent residues, which could be converted into several valueadded products. Proficient recycle of distillation waste of aromatic plants in marginal lands will aid to sequester C in soil and enhance the biomass yield. Improvement in the livelihood of farmers especially in developing nations through rise in production and income diversification would encourage farm-ers to reclaim their marginal lands and accelerate their transition to aromatically cultivable lands.

**KEYWORDS**

aromatic plants, carbon sink, climate change, economical viability, land reclamation, organic wastes

**1**  | **INTRODUCTION**

The current atmospheric CO2 level is > 400 ppm, which needs to be reduced and C sequestration (CS) becomes im-perative to achieve this. Growing aromatic biomass for CS in erosion vulnerable C deficit marginal soils could fetch environmental benefits. The unsuitable conventional crop-ping patterns on the marginal lands had accelerated wind

and water erosion (Bhattacharyya et al., 2015). Marginal lands do not contribute to food production (Skevas, Swinton, & Hayden, 2014) and therefore, production of aromatic plants on them is unlikely to affect food and feed supplies. Utilization of aromatic plantbased residue for CS in the marginal soils and for the biofuel production pro-vides economical profits to the farmers via adaptable cash crops.

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**2**  | **MARGINAL LANDS**

Marginal lands are the barren fields generally unsuitable, degraded, fallow agricultural, previously contaminated, un-der-utilized and wastelands (Gibbs & Salmon, 2015). These include areas with constraint rainfall, extreme temperature, steep terrain, salt affected, waterlogged, marshy, stony and rocky soils. Marginal lands are prone to high erodibility and have poor drainage due to edaphic, climatic or environmental restrictions (Gelfand et al., 2013) and are of trivial profitabil-ity for the native traditional crops.

**3**  | **WHY AROMATIC PLANTS FOR**

**THE CULTIVATION OF MARGINAL LANDS?**

Aromatic plants are essential oilbearing industrial or com-mercial crops, which are tolerable to stress conditions such as soil pH variability, heavy metal toxicity and drought. Essential oils are produced by aromatic plants as second-ary metabolites; these are volatile natural compounds with strong aroma due to richness in terpenes and completely free from the risk of toxic heavy metals contamination (Gupta, Verma, Khan, & Verma, 2013) . Aromatic plants give higher essential oil yield under stressed conditions because second-ary metabolites production is always high during the envi-ronmental stress. Conservation agricultural practices are pragmatic for the aromatic plants as they require less manual care and residue recycling with least soil disturbance can facilitate soil CS. No economical loss ascribing disease oc-currence or cultivation issue in the aromatic plants has been reported yet. But some of the barriers for the aromatic plant growers are lack of agro-technology awareness, adequate market information, limited storage facilities and complex quality assessment procedure of essential oils. Highvalue aromatic plants can be successfully grown on the marginal lands owing their potential to grow on impoverish soils, lower nutrient requirements, better water use efficiency and diminish air pollution (Litskas, Chrysargyris, Stavrinides, & Tzortzakis, 2019). Marginal lands constrict agricultural pro-ductivity and profitability but could be utilized for the pro-duction of aromatic plants, which would not only ameliorate it but also provide higher benefit-cost-ratio and sequester C (Basak, Saha, Chinchmalatpure, & Manivel, 2018; Liu, Liu, Yao, & Ma, 2016).

Essential oil extracted from the fresh aromatic herbs through steam or hydro distillation process consequences huge amount of by-products, i.e; distillation waste biomass and spent liquid waste (hydrosol). Each year India alone pro-duces almost 6.0 million tons of aromatic spent residues (Rout, Nannaware, & Rajasekharan, 2015), which are converted into valueadded products such as compost, biochar, biofuel,

**Highlights**

* Rehabilitation of marginal lands and their trans-formation from CO2 source to sink
* Highvalue aromatic plants for sequestering C in marginal soils
* Approach to combat environmental challenges

biogas, biopesticides, etc. aiding in reducing CO2 emission and proved remunerative to farmers (Saha & Basak, 2019). Distillation waste of *Cymbopogon flexuosus* L., *Ocimum* *basilicum* L. and *Mentha arvensis* L. has the potential forsorption of some heavy metals and dyes. *Cymbopogon flex-uosus* L. distillation waste can be effectively used as fodder,soil mulch, biogas and biochar while its bio-oil as renewable fuel. *Cymbopogon flexuosus* L., *Cymbopogon martini* L. and *Lavandula angustifolia* L. were used for the production ofethanol. Steam distillation of aromatic plants overcomes the recalcitrant nature of biomass and Zheljazkov et al. (2018) in their study have revealed that it was verily advantageous to use distillation waste of aromatic plants for the biofuel production over traditional *Panicum virgatum* L. because steam-treated biomass can easily be converted to ethanol. Aromatic distilla-tion wastes are rich in the organic matter and can be used as a soil amendment aiding in the sustainable production systems and also for soil CS. Soil microbes decompose organic matter which either gets assimilated and incorporated into biomass or immobilized as soil biomass. Removal of biomass resi-due alters soil microbial community structure accompanied with increase in C degrading genes. *Mentha arvensis* L. dis-tillation based biochar amended highly acidic soil and subse-quently enhanced its fertility status and also reduced soil lead availability. Biochar prepared from the distillation biomass of *Cymbopogon winterianus* Jowitt increased nutrient use efficiency and plant productivity. Distillation waste biomass of *Cymbopogon martini* L. proved to be an effective source of soil potassium. Vermicompost prepared from the residual biomass of *Mentha arvensis* L., *Cymbopogon winterianus* Jowitt and *Pelargonium graveolens* L’Her increased the soil organic C, available nutrients and microbial population and hence being lucrative by significantly improving the biomass yield. Root knot infestations were reduced by *Mentha arven-sis* L., *Cymbopogon flexuosus* L. and *Cymbopogon martini* L. based vermicompost. Major constituents of the aromatic distillation biomass waste are cellulose (35%–40%), hemicel-lulose (25%–30%) and lignin (15%–20%) (Rout et al., 2015), therefore, can be recycled as an alternative source of com-mercial cellulose. Aromatic hydrosol contains appreciable amount of valuable oils and compounds, having fungitoxic, antibacterial, insecticidal, antioxidant, antiradical and anti-acetylcholinesterase activities (Saha & Basak, 2019).

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**4** | **SEQUESTERING C IN MARGINAL LANDS**

Marginal lands are missing sinks for CS and due to negli-gence in their sustainable utilization, these lands end up as being source of atmospheric CO2. Degraded lands emit C at the rate 0.20–0.40 Pg year−1. Solely wind and water ero-sions occurring on degraded lands accounted for 0.21–0.26 Pg and 6 Tg C emissions per year, respectively. Lal. (2004) had revealed the Indian scenario of C emission through soil erosion, which is provided in Table S1. Cultivation of mar-ginal lands would restore its soil functioning through CS and eventually contributing towards the mitigation of global warming. Table S2 shows the Indian scenario of soil or-ganic CS potential through the restoration of degraded soils (Lal, 2004). Marginal soils have scruple C status but there exists a colossal interlude between current and inherent soil C content. This proffers marginal lands relatively higher soil CS potential compared to their non-degraded counterparts (Bhattacharya et al., 2016). Proper soil management provides CS and food security (Bampa et al., 2019), and therefore, soil organic C dynamics have gained global attention. To better understand the marginal soil dynamics, it is crucial to under-stand its translational properties. During the gradual conver-sion of marginal lands to productive lands, there is effective repository of soil organic C. Marginal lands under semiarid regions have substantial soil CS potential (Guoju, Yanbin, Qiang, Jing, & Ming, 2020).

While producing large scale aromatic plant bio-mass, climate change via CS becomes paramount. Singh, Guleria, Prakasa Rao, and Goswami (2013) have evaluated the CS potential accompanied by economics generated from essential oil production of *Chrysopogon zizanioides* L., *Cymbopogon martini* L. and *Cymbopogon flexuosus* L., presented in the Table 1. Tripathi (2012) studied the biomass production and CS rate of *Ocimum sanctum* L., which is briefly stated in Table S3. Soil CS through aro-matic *Chrysopogon zizanioides* L. model is a very suitable system for marginal soils. The details of these aromatic plants which are crucial with reference to CS are pro-vided in the Table S4. Council of Scientific and Industrial Research (CSIR) Aroma mission project report provided

1. well-experimented analysis demonstrating the effective-ness of aromatic plantation for CS on the marginal lands in the different parts of India (Table 2). These facts also exhibit the suitability of aromatic plants for inclusion in diversified cropping systems on marginal lands. CS under aromatic plantations would help in the reclamation of mar-ginal lands (fix and add large quantities of the standing biomass C and crop residue soil C) along with climate change mitigation and without posing any risk to food se-curity. Growing aromatic plants on non productive mar-ginal lands might convert them into productive lands and improve the sustainability of existing conventional crop-ping systems through the reduction of agricultural runoff and enhancement in CS.

**T A B L E 1** Carbon sequestrationpotential of some aromatic plants

**T A B L E 2** Biomass yield and carbonsequestration potential of some aromatic plants cultivated on the different marginal lands of India under the Council of Scientific and Industrial Research (CSIR) Aroma Mission Project from April 2017 to February 2020

|  |  |  |  |
| --- | --- | --- | --- |
|  | ***Chrysopogon*** | ***Cymbopogon*** | ***Cymbopogon*** |
|  | ***zizanioides* L.** | ***martini* L.** | ***flexuosus* L.** |
| Mean C sequestered in Biomass | 15.24 | 6.14 | 5.38 |
| (Mg ha−1 year−1) |  |  |  |
| Mean C sequestered in Soil (Mg | 5.75 | 2.79 | 3.08 |
| ha−1 year−1) |  |  |  |
| Benefit-cost-ratio | 2.30 | 2.75 | 1.97 |
| Source: Singh et al., (2013). |  |  |  |



|  |  |  |  |
| --- | --- | --- | --- |
|  | **Area covered** | **Biomass yield** | **Biomass Carbon** |
|  | **(ha)** | **(Mg)** | **Sequestered (Mg)** |
| *Chrysopogon zizanioides* L. | 243.58 | 608.95 | 306.20 |
| (Root) |  |  |  |
| *Chrysopogon zizanioides* L. |  | 6089.50 | 3077.02 |
| (Shoot) |  |  |  |
| *Cymbopogon martini* L. | 565.52 | 15551.80 | 8206.69 |
| *Cymbopogon flexuosus* L. | 417.43 | 11688.04 | 5195.33 |
| *Cymbopogon winterianus* | 47.00 | 1222.00 | 611.00 |
| Jowitt |  |  |  |



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**5**  | **INDIAN SCENARIO**

Non-conventional aromatic plants are in great demand worldwide. India has several aromatic plantbased tradi-tional cottage industries and about 50 aromatic plants are sought after in trade and industries (Saha & Basak, 2019). Indian trade in the aromatic and medicinal products is es-timated to be approximately 120 million US$ per annum. India is the largest exporter of essential oils, and Table 3 shows the trading data of some aromatic-based essential oils for the year 2013–14 (Tripathi, Suresh, Kumar, & Khan, 2016). Now the question arises that does India have enough

**T A B L E 3** Export and import data of some aromatic plantbasedessential oil in India for the year 2013–14



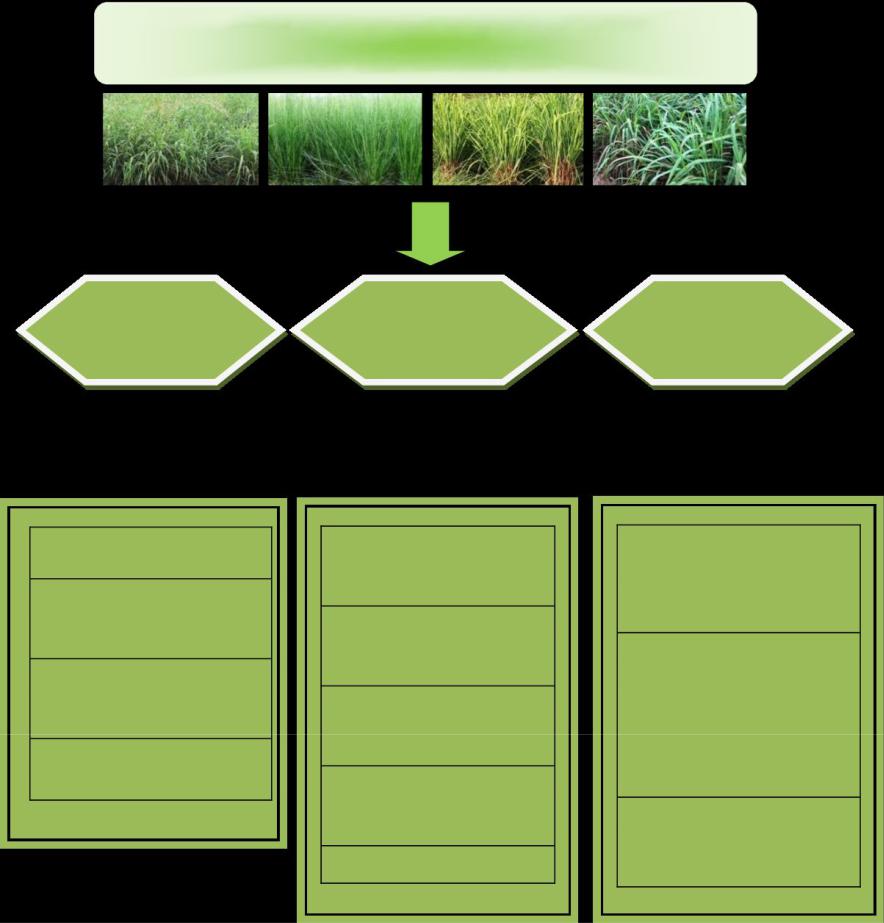
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| --- | --- | --- |
|  | **Export** | **Import** |
| **Essential oil of aromatic plants** | **(Tons)** | **(Tons)** |
| *Mentha piperita* L. | 3790.5 | 21.5 |
| *Mentha spicata* L. | 369.6 | 10.0 |
| *Cymbopogon martini* L. | 52.1 | <1.0 |
| *Cymbopogon flexuosus* L. | 182.7 | 0.3 |



Source: Tripathi et al., (2016)

marginal lands to meet ever increasing global need for the aromatic plants? Marginal lands in India are determinant to the poor as large tracts of the degraded lands are owned by them. 65% of farms are considered sustainability marginal (<1 ha) comprising nearly 400 million people with about 40% of them as vulnerable, marginalized and food inse-cured (Bhattacharyya et al., 2015) . Small lands (≤2 ha) in the rain-fed areas constitute 80% of the farmer holdings, which accounts for > 50% of the agricultural output. The per capita land availability is estimated to dwindle to 0.19 ha by 2035, and the per capita agricultural land availability is 0.48 ha. The status of land degradation in India is presented in the Table S5. India is experiencing a huge monetary loss from the degraded lands (declining crop productivity, land use intensity, changing cropping patterns, and high input use). Poverty is higher among the marginal farmers having smaller land sizes, to overcome this they need to increase their area more under crop diversification like highvalue ar-omatic crops. In India, total marginal land is 39,204,223 ha (Edrisi & Abhilash, 2016), 146.8 mha land is degraded, 6.7 mha (6.7 × 106 ha) land is salt affected, and 46.67 mha is wasteland. The average soil erosion nationwide is approxi-mately 16.4 ton ha−1 year−1 resulting in the total annual loss

Multifunctional perspective for the production of aromatic



plants on marginal lands

**F I G U R E 1** An outline showcasing thesuitability of aromatic plants for marginal lands

Carbon Environmental

Sequestration Sustainability

|  |  |  |
| --- | --- | --- |
| High biomass yield | Reclamation | of |
|  | marginal lands |  |
| C sequestered | in |  |
| biomass and soil | Winder environmental | |
|  | adaptability |  |

Aromatic spent waste

utilization Conservation agricultural practices

Conversion of waste

lands to C sinks Climate change mitigation

Biofuel Production

Economical

Welfare

Low input but high

output due to essential

oil production

Additional incentives

from the production

of value added

products from

aromatic spent waste

1. sequestration incentives and C credits

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of 5.3 billion tons soil (Bhattacharyya et al., 2015). About 6,000 million tons of the top fertile soils are lost annually heading towards low agricultural production of about 2.7 million tons (Bhan, 2013).

The analysis report of Desertification and Land Degradation Atlas of India (2016) reveals that 96.40 mha area is undergoing the process of land degradation i.e; 29.32% of the total geographic area during 2011–13. There is cumulative increase of 1.87 mha area undergo-ing the process of land degradation during the time frame 2003–05 and 2011–13. Around 3.63 mha productive lands had degraded and 0.74 mha land had been converted to high severity degradation class from low severity. The detrimental process of land degradation is water erosion (10.98% in 2011–13 and 10.83% in 2003–05) followed by vegetation degradation (8.91% in 2011–13 and 8.60% in 2003–05) and subsequently the wind erosion (5.55% in 2011–13 and 5.58% in 2003–05). India is signatory to the United Nations Convention on Combating Desertification (UNCCD) and is committed to achieve the land degrada-tion neutral status by 2030. The 14th session of Conference of the Parties (COP 14) of UNCCD was held in India, 2019, deducing that India is highly vulnerable to climate change and land degradation being a critical issue with nearly 30% of land coming under the degradation status. Most affected are the peasants, constituting about 80% of the total farm-ers own < 2 ha land. India will restore an additional 5 mha of degraded land by 2030, raising the land to be restored to 26 mha.

The concept of utilization of marginal lands for the pro-duction of aromatic plants delivers a wise step for the re-habilitation of the degraded lands, management of the crop diversity, mitigation of global warming and would also even-tually add to our national economy is illustrated in Figure 1. Future research prospectives should emphasize on the con-duction of long-term field experiments on the marginal lands for the evaluation of CS potential and economic plausibility of the various aromatic plants. This would conjointly deliver a win–win approach towards restoration of marginal soils and sustainable ecosystems.

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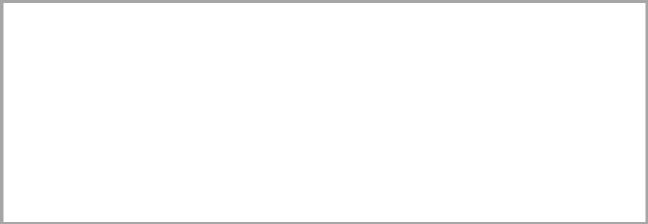
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**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section.



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