The Pharma Innovation Journal 2022; SP-11(8): 1829-1832

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(8): 1829-1832

www.thepharmajournal.com
Received: 25-05-2022
Accepted: 30-06-2022

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Carbon sequestration potential of tree species for rehabilitation of deep Chambal ravines of Madhya Pradesh

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Abstract
The present study was conducted at a university experimental site at the village Aisah of Morena district of M. P., near the bank of Chambal River during 2020-21 to 2021-22 emphasized the plantation of several species of native forest trees and fruit trees plants for the control and reclamation of ravines and their management for sustainable livelihood security. Plantation of different fruit trees *Moringa oleifera*, *Terminalia arjuna*, *Azadirachta indica*, *Acacia nilotica*, *Millettia pinnata*, *Albizia lebbeck*, *Gmelina arborea*, *Dalbergia sissoo* and *Justicia adhatoda* were raised during 2012 at 3x3 m spacing. The pooled mean effect of both the years of the carbon weight of the tree varies within different tree species. Data revealed that the highest carbon sequestration of the tree was observed for *Moringa oleifera* followed with a value of (1063.33 pounds/year/plant), followed by *Albizia lebbeck* (632.41 pounds/year/plant), *Azadirachta indica* (296.77 pounds/year/plant), *Acacia nilotica* (271.86 pounds/year/plant), *Dalbergia sissoo* (269.87 pounds/year/plant), *Terminalia arjuna* (137.72 pounds/year/plant), *Millettia pinnata* (109.11 pounds/year/plant) *and Gmelina arborea* (57.05 pounds/year/plant). While the lowest carbon sequestration of the tree was recorded in *Justicia adhatoda* with a value of (1.76 pounds/year/plant).

Keywords: Biomass carbon, Carbon sequestration, Chambal region, Rehabilitation, Ravines, Sustainability, Tree species

Introduction
In India, Madhya Pradesh state of India alone has higher biomass production (above & below ground carbon stock) and improvement in soil properties. Carbon sequestration is one of the important processes of storage of CO_2 or other forms of carbon to mitigate environmental issues like global warming, and the greenhouse effect and is one of the important clauses of the Kyoto Protocol, through biological, chemical or physical processes; CO_2 is sequestered from the atmosphere. The Kyoto Protocol to the UN Framework Convention on Climate Change has provided a vehicle for considering the various effects of carbon sinks and sources, as well as addressing issues concerned with fossil fuel emission. Growing concern about climate change and concerned problems led to the research quantifying the overall effects of trees from the urban area on atmospheric carbon dioxide. Trees from Urban areas also affect temperatures of air and building energy use, and consequently alter carbon release from numerous urban sources. Thus, urban trees potentially influence the climate at the local level, carbon cycles, energy use and climate change. Urban trees affect climate change, but these trees are often disregarded because their environmental services are not so well understood or quantified. Trees act as a sink for carbon dioxide by fixing carbon during photosynthesis and storing carbon as biomass. The clear long-term CO_2 origin dynamics of the forests change through time as trees grow, die, and decay. Human influences on forests can further affect the CO_2 source dynamics of urban forests through such components as fossil fuel emissions and harvesting of biomass. The trees capture CO_2 by fixing carbon during the photosynthesis process and accumulating extra carbon as biomass. The plant grows through the natural process of photosynthesis, in which carbon dioxide is captured and stored in cells of plants with growth.

Soil carbon sequestration through the restoration of soil organic matter can further reverse land degradation and restore soil “health” through restoring soil biota and the array of associated ecological processes. The rapid increase in global carbon dioxide level in the atmosphere in the recent past and its potential for adversely impacting the world climate has raised concerns the world over.

The continued rise in atmospheric CO_2 concentration (~400 ppm) and its adverse effect on global climate makes it necessary to explore all possible mitigation strategies. Among various strategies to reduce the atmospheric CO_2 concentration, enhancing the natural carbon sequestration capabilities of degraded or underproductive lands by vegetation/afforestation is the major thrust area. Lands with a degraded vegetation cover having lower carbon biomass density (the mass of carbon per unit area) than the potential for that site must be identified as potential sites for improving as a carbon sink. The Kyoto protocol proposed carbon reduction through decreasing fossil fuel emissions or accumulating C in vegetation and soil (Oelbermann *et al.*, 2004) [5].

Materials Method

Description of the study area: The present study was conducted at the university experimental site at the village Aisah of Morena district of M. P., near the bank of the Chambal River and is about 80 Km from the university headquarter. The needed research work on the control and reclamation of ravines and their management for sustainable livelihood security was initiated area of excellence of the research work plan at Aisha village, Morena district, M.P. The geographical location of the study area is 26° 40'40.84 N latitude and 78° 06'29.21E longitude with an altitude ranges 150 to 240 m above mean sea level. In both these studies, a heavy emphasis was laid on the plantation from the very beginning several species of native forest trees and fruit trees plants were evaluated on different sloppy and levelled patches of ravine land. The experiments were started on 2020-21 to 2021-22.

Carbon sequestration

Carbon content in the tree

The tree's total volume generally contains 50% of the average carbon. Therefore, the weight of carbon in the plant is 50 per cent of the plant's dry weight

Weight of carbon dioxide sequestered in the tree

CO_2 has one molecule of Carbon and 2 molecules of Oxygen. The atomic weight of Carbon is 12.001115, whereas Oxygen's atomic weight is 15.9994. Hence the estimated weight of CO_2 is, C+2*O = 43.999915; and CO_2: C ratio is 43.999915/12.001115 = 3.6663. Hence, the weight of CO_2 stored in the plant is estimated, by multiplying 3.6663.

Weight of CO_2 sequestered in the tree per year

The weight of CO_2 sequestered in the plant per year = Weight of CO_2 stored in plant/ age of the plant (Clark *et al.*, 1986) [2].

Result -

CO_2 sequestered in the tree (pounds/plant)

In the year 2020-21, the experiment result showed that the total weight of carbon dioxide that was sequestered by tree species varies significantly with different tree species. From the table and figure it was confirmed that the amount of carbon dioxide sequestered was maximum in (9717.1 pounds/plant) was demonstrated by *Moringa oleifera* plantation followed by *Albizia lebbeck* (5763.82), *Azadirachta indica* (2673.42), *Acacia nilotica* (2460.19 pounds/plant), *Dalbergia sissoo* (2458.57 pounds/plant), *Terminalia arjuna* (1271.32 pounds/plant), *Millettia pinnata* (987.70 pounds/plant) *and Gmelina arborea* (507.19 pounds/plant). Minimum carbon dioxide sequestration of the tree was found in *Justicia adhatoda* (14.08 pounds/plant).

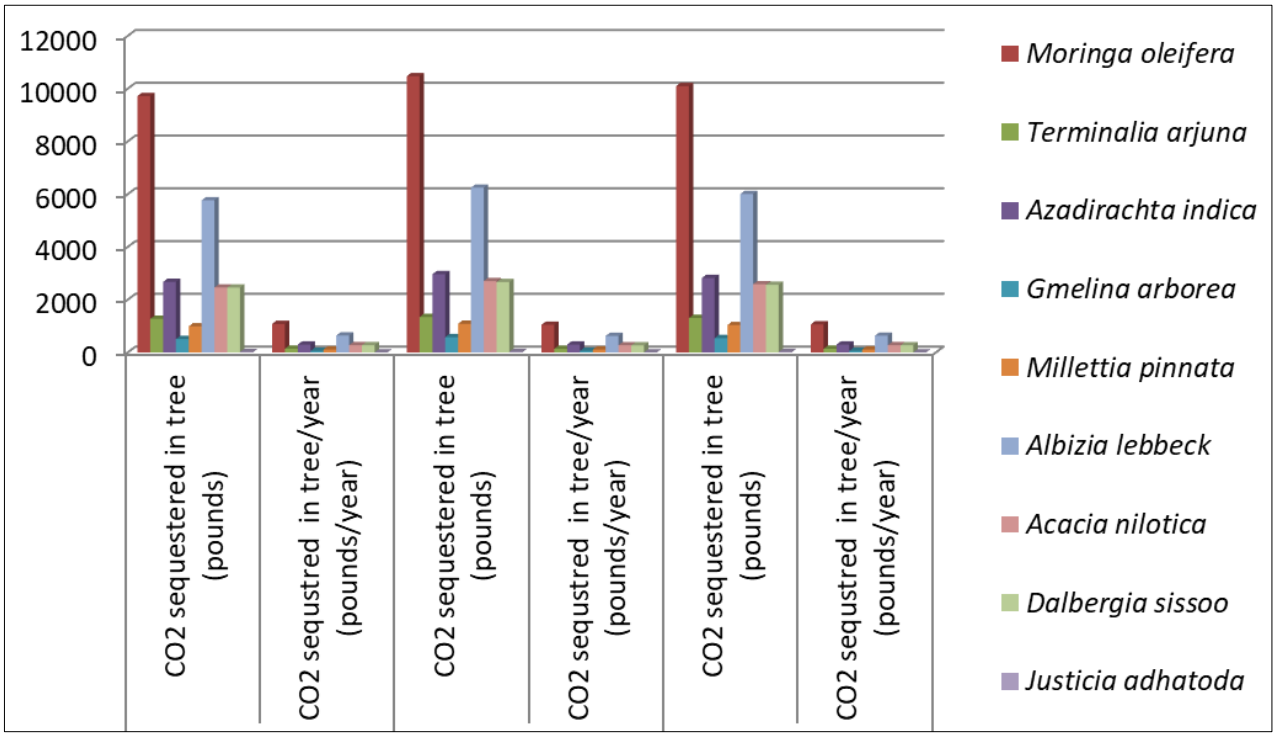

Fig 1: CO_2 sequestered and CO_2 sequestered/year by different tree species

Table 1: CO_2 sequestered (pounds) and CO_2 sequestered (pounds/year) by different tree species

S. No.	Treatment	Year 2020-21		Year 2021-22		Pooled	
		CO_2 sequestered in tree (pounds)	CO_2 sequestered in tree (pounds/ year)	CO_2 sequestered in tree (pounds)	CO_2 sequestered in tree (pounds/ year)	CO_2 sequestered in tree (pounds)	CO_2 sequestered in tree (pounds/ year)
T_1	*Moringa oleifera*	9717.1	1079.68	10469.8	1046.98	10093.41	1063.33
T_2	*Terminalia arjuna*	1271.32	141.26	1341.86	134.19	1306.59	137.72
T_3	*Azadirachta indica*	2673.42	297.05	2964.90	296.49	2819.16	296.77
T_4	*Gmelina arborea*	507.19	56.35	577.53	57.75	542.36	57.05
T_5	*Millettia pinnata*	987.70	109.74	1084.85	108.49	1036.27	109.11
T_6	*Albizia lebbeck*	5763.82	640.42	6243.9	624.39	6003.86	632.41
T_7	*Acacia nilotica*	2460.19	273.35	2703.64	270.36	2581.92	271.86
T_8	*Dalbergia sissoo*	2458.57	273.17	2665.74	266.57	2562.16	269.87
T_9	*Justicia adhatoda*	14.08	1.56	19.60	1.96	16.84	1.76
	S.Em.±	1011.72	112.41	1068.28	106.83	735.66	77.54
	C.D.	3033.15	337.02	3202.69	320.27	2119.19	223.36

A perusal of data during the year 2021-22, the experiment also observed that the carbon dioxide sequestration of the tree of the plant varies significantly within different tree species. Data presented in table 1 and figure 1 revealed that the highest carbon dioxide sequestration of the tree of the plant was observed for *Moringa oleifera* followed by a value of (10469.8 pounds/plant), followed by *Albizia lebbeck* (6243.9 pounds/plant), *Azadirachta indica* (2964.90 pounds/plant), *Acacia nilotica* (2703.64 pounds/plant), *Dalbergia sissoo* (2665.74 pounds/plant), *Terminalia arjuna* (1341.86 pounds/plant), *Millettia pinnata* (1084.85 pounds/plant) *and Gmelina arborea* (577.53 pounds/plant), While the lowest carbon dioxide sequestration of the tree was recorded in *Justicia adhatoda* with a value of (19.60 pounds/plant).

The pooled analysis effect the carbon dioxide weight of the tree significantly within different tree species. Data presented in table 1 and figure 1 revealed that the highest carbon dioxide sequestration of the tree was observed for *Moringa oleifera* followed by with a value of (10093.4 pounds/plant), followed by *Albizia lebbeck* (6003.86 pounds/plant), *Azadirachta indica* (2819.16 pounds/plant), *Acacia nilotica* (2581.92 pounds/plant), *Dalbergia sissoo* (2562.16 pounds/plant), *Terminalia arjuna* (1306.59 pounds/plant), *Millettia pinnata* (1036.27 pounds/plant) *and Gmelina arborea* (542.36 pounds/plant), While the lowest carbon dioxide sequestration of the tree was recorded in *Justicia adhatoda* with a value of (16.84 pounds/plant).

CO_2 sequestered in tree pounds/year/plant

In the year 2020-21, carbon sequestration of weight CO_2 stored in trees and CO_2 sequestered in trees/years have been tabulated in table 1. It was observed that the carbon sequestration varies significantly with different tree species. From the table and figure it was confirmed that the amount of carbon sequestered was maximum in (1079.68 pounds/year/plant) was demonstrated by *Moringa oleifera* plantation followed by *Albizia lebbeck* (640.42 pounds/year/plant), *Azadirachta indica* (297.05 pounds/year/plant), *Acacia nilotica* (273.35 pounds/year/plant), *Dalbergia sissoo* (273.17 pounds/year/plant), *Terminalia arjuna* (141.26 pounds/year/plant), *Millettia pinnata* (109.74 pounds/year/plant) *and Gmelina arborea* (56.35 pounds/year/plant). Minimum carbon sequestration of the tree was found in *Justicia adhatoda* (1.56 pounds/year/plant).

A perusal of data during the year 2021-22 in the experiment also observed that the carbon sequestration of the tree (pounds/year/plant) varies significantly within different tree species. Data presented in table 1 and figure 1 revealed that the highest carbon sequestration of the tree of the plant was observed for *Moringa oleifera* followed by with a value of (1046.98 pounds/year/plant), followed by *Albizia lebbeck* (624.39 pounds/year/plant), *Azadirachta indica* (296.49 pounds/year/plant), *Acacia nilotica* (270.36 pounds/year/plant), *Dalbergia sissoo* (266.57 pounds/year/plant), *Terminalia arjuna* (134.19 pounds/year/plant), *Millettia pinnata* (108.49 pounds/year/plant) *and Gmelina arborea* (57.75 pounds/year/plant), While the lowest carbon sequestration of the tree was recorded in *Justicia adhatoda* with a value of (1.96 pounds/year/plant).

The pooled mean effect of the carbon weight of the tree varies within different tree species. Data presented in table 1 and figure 1 revealed that the highest carbon sequestration of the tree was observed for *Moringa oleifera* followed by with a value of (1063.33 pounds/year/plant), followed by *Albizia lebbeck* (632.41 pounds/year/plant), *Azadirachta indica* (296.77 pounds/year/plant), *Acacia nilotica* (271.86 pounds/year/plant), *Dalbergia sissoo* (269.87 pounds/year/plant), *Terminalia arjuna* (137.72 pounds/year/plant), *Millettia pinnata* (109.11 pounds/year/plant) *and Gmelina arborea* (57.05 pounds/year/plant). While the lowest carbon sequestration of the tree was recorded in *Justicia adhatoda* with a value of (1.76 pounds/year/plant).

Discussion-

The carbon dioxide weight of the tree varies significantly within different tree species. Data presented in table 1 revealed that the highest carbon dioxide sequestration pooled year of the tree was observed for *Moringa oleifera* followed by with a value of (10093.4 pounds/plant), followed by *Albizia lebbeck* (6003.86 pounds/plant), *Azadirachta indica* (2819.16 pounds/plant), *Acacia nilotica* (2581.92 pounds/plant), *Dalbergia sissoo* (2562.16 pounds/plant), *Terminalia arjuna* (1306.59 pounds/plant), *Millettia pinnata* (1036.27 pounds/plant) *and Gmelina arborea* (542.36 pounds/plant), While the lowest carbon dioxide sequestration of the tree was recorded in *Justicia adhatoda* with a value of (16.84 pounds/plant). Data presented in table 1 revealed that the carbon sequestration result was non-significant and the highest carbon sequestration of the tree in the pooled year was observed for *Moringa oleifera* followed by a value of (1063.33 pounds/year/plant), followed by *Albizia lebbeck* (632.41 pounds/year/plant), *Azadirachta indica* (296.77 pounds/year/plant), *Acacia nilotica* (271.86 pounds/year/plant), *Dalbergia sissoo* (269.87 pounds/year/plant), *Terminalia arjuna* (137.72

pounds/year/plant), *Millettia pinnata* (109.11 pounds/year/plant) *and Gmelina arborea* (57.05 pounds/year/plant), While the lowest carbon sequestration of the tree was recorded in *Justicia adhatoda* with a value of (1.76 pounds/year/plant). The above findings followed a similar trend with the carbon sequestration levels Kaur *et al.* (2004) [3] experimented on about six-year-old tree species of *Acacia nilotica, Dalbergia sissoo* and *Prosopis juliflora*, with two species of grasses, *Desmostachya bipinnata* and *Sporobolus marginatus*, in the subplots. The total carbon storage in the trees is 1.18 to 18.55 Mg C/ha/yr. and carbon input in net primary production varied between 0.98 to 6.50 Mg C/ha/yr. Carbon flux in net primary productivity increased significantly due to the integration of *Prosopis juliflora* and *Dalbergia sissoo* with grasses. Mir (2010) [4] similar result that the total carbon sequestration rate obtained from above-ground biomass of *Tectona grandis, Madhuca indica, Dalbergia sissoo, Acacia nilotica, and Azadirachta indica* was 11.94 kg/tree, 20.84 kg/tree, 14.35 kg/tree, 10.13 kg/tree, and 15.67 kg/tree respectively. Similar results find Sharma *et al.* (2016) [6] the total weight of CO_2 sequestrated by tree species varies significantly with different multipurpose tree species. It was observed that the amount of carbon dioxide sequestered was highest in *Eucalyptus tereticornis* with 1478.85 kg/tree followed by *A. lebbeck* with 1473.37 kg/tree. Chandra and Bhardwaj (2018) [1] investigation was carbon sequestration potential was highest in *A. lebbeck* and lowest in *P. pinnata* in bhata land soil.

Conclusion

Based on the results obtained from the study it can be concluded that the presence of tree species at a certain place has remarkable effects on carbon sequestration. Out of nine forest species *Moringa oleifera***,** *Terminalia arjuna*, *Azadirachta indica*, *Acacia nilotica*, *Millettia pinnata*, *Albizia lebbeck*, *Gmelina arborea*, *Dalbergia sissoo* and *Justicia adhatoda*. *Moringa oleifera* may have a good potential for carbon dioxide sequestration compared to other species. Based on the result it can be concluded that *Moringa oleifera* is better in terms of carbon content, and CO_2 sequestration as compared to *Terminalia arjuna, Azadirachta indica, Acacia nilotica, Millettia pinnata, Albizia lebbeck, Gmelina arborea, Dalbergia sissoo* and *Justicia adhatoda*.

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