Carbon sequestration in agroforestry and pasture systems in arid northwestern India

Shamsudheen Mangalassery[1,*], Devi Dayal[1], S. L. Meena[2] and Bhagirath Ram[3]

[1]Central Arid Zone Research Institute, Regional Research Station, Kukma–Bhuj 370 105, India
[2]Division of Agronomy, Indian Agricultural Research Institute, Pusa, New Delhi 110 012, India
[3]Directorate of Rapeseed-Mustard Research, Bharatpur 321 303, India

Carbon sequestration has been suggested as a means to help mitigate the increase in atmospheric carbon dioxide concentration. Silvipastoral systems can better sequester carbon in soil and biomass and help to improve soil conditions. In the present study, carbon sequestration was quantified both in biomass and soil in two pasture systems (*Cenchrus ciliaris* and *Cenchrus setegerus*), two tree systems (*Acacia tortilis* and *Azadirachta indica*) and four silvipastoral system (combination of one tree and on grass) in arid northwestern India. The silvipastoral system sequestered 36.3% to 60.0% more total soil organic carbon stock compared to the tree system and 27.1–70.8% more in comparison to the pasture system. The soil organic carbon and net carbon sequestered were greater in the silvipastoral system. Thus, silvipastoral system involving trees and grasses can help in better sequestration of atmospheric system compared with systems containing only trees or pasture.

Keywords: Arid soils, carbon sequestration, grasses, Kachchh, silvipasture.

SINCE the industrial revolution, there has been drastic increase in the concentration of atmospheric carbon dioxide and other greenhouse gases (GHGs). The major reasons attributed to the global warming and associated climatic changes are increased concentration of GHGs in the atmosphere[1]. The global atmospheric CO_2 concentration increased from 280 ppm in 1750 to 379 ppm in 2005 which has been attributed primarily to fossil fuel use and land-use change[2] with a total increase of 1.9 ppm per year. Apart from CO_2, the atmospheric concentration of CH_4 has increased to 1774 ppb in 2005 from the pre-industrial value of 715 ppb (148% increase). N_2O continues to rise at the rate of 0.26% per year, measured at 319 ppb in 2005, 18% higher than its pre-industrial value[2]. In another estimate, the atmospheric CO_2 concentration is expected to double until the middle to late 21st century, with implications for a temperature rise between 1.5°C and 4.5°C (ref. 3). Current strategies for coping with global warming include reducing fossil fuel combustion as well as curbing emission of other GHGs and increasing carbon sequestration[4].

Atmospheric carbon can be sequestered in long-lived carbon pools of plant biomass both above and below ground or recalcitrant organic and inorganic carbon in soils and deeper subsurface environments[5]. Apart from offsetting CO_2 emissions and global warming, sequestration of carbon in soils also helps to improve soil quality and productivity by improving many physical, chemical and biological properties of soils such as infiltration rate, aeration, bulk density, nutrient availability, cation exchange capacity, buffer capacity, etc.[6]. Soil organic carbon sequestration is more important in arid regions, where soils are inherently low in organic carbon content. In arid environments, trees, pastures and agroforestry systems are important for carbon sequestration strategies[7,8]. Articles 3.3 and 3.4 of the Kyoto protocol provide rationale for the importance of managing dry lands to sequester carbon via restoration of desertified lands and planting perennial tree/woody components[9]. Systems involving trees act as carbon sinks due to their ability to sequester atmospheric carbon in deep soil profiles and various tree components[10,11]. According to the Kyoto protocol, only carbon newly sequestered through agroforestry practices is considered as carbon credits and can be sold to industrialized countries to meet their emission reduction targets, although there is pressure to include soil carbon also[12].

Accurate information about the spatial distribution of carbon both in soil and vegetation in the ecosystem is important for better understanding of biogeochemical processes and formulation of policies and actions. The Kachchh in arid northwestern India contains a very fragile ecosystem which is threatened by increased human activities in terms of overgrazing, urbanization and rapid industrialization. Information on carbon sequestration under various land-use systems is very meagre for this important but fragile ecosystem of northwestern India. Therefore, this study aims to quantify carbon sequestration in this predominantly arid region of northwestern India.

The study was carried out in an established pasture and silvipastoral systems in Kachchh, Gujarat in the arid northwestern part of India at the research farm of Central Arid Zone Research Institute, Regional Research Station, Kukma–Bhuj. The study area is located at 23°12′N to 23°13′N and 69°47′E to 69°48′E. The region experiences scanty, erratic and irregular rainfall of 397 mm in 11 rainy days (average for 1998 to 2013) with a coefficient of variation of 73% among years. The monsoon starts generally in the first week of July and recedes in middle of September. Drought is a regular phenomenon in the region. The annual minimum temperature ranges from 1°C to 8°C and maximum temperature ranges from 39°C to 45°C. The soils are sandy loam to loamy sand in texture and are classified as Ustochreptic camborthids. The soils are alkaline with pH 8.36 to 8.41 and non-saline (electrical conductivity 0.3 to 0.34 dSm^{-1}). Soil nitrogen

*For correspondence. (e-mail: shamsudheenm@gmail.com)