CARBON SEQUESTRATION IN SITES REFORESTED IN NORTHERN MEXICO

J. Návar[1], and F.J. Rodriguez[2]

[1]*Departamento de Física y Química. CIIDIR-IPN Unidad Durango. Calle Sigma sin número. Fraccionamiento 20 de Noviembre 2. Durango, Dgo. CP 34220. México. Email: josedejesusnavar@yahoo.com.mx*

[2]*Facultad de Ciencias Forestales, UANL. Carr. Nacional Km 145. Linares, N. L., México. 67700. Email:jesurgz@hotmail.com*

ABSTRACT

Reforestation is an important mean to protect soils, to restore habitat for plants and animals, to regulate the hydrological cycle, to recharge aquifers, to produce oxygen and to sequester carbon dioxide. Global warming concerns are prompting reforestation practices and studies dealing with biomass production and carbon sequestration by exotic and native species. This research presents information on biomass and carbon sequestration projections in reforested sites of northern Mexico. A total of 124 sampling plots were sampled for dasometric features and biomass components in the Mexican states of Durango, Coahuila, and Nuevo Leon of the Eastern and Western mountain ranges of northern Mexico. Results showed the potential carbon sequestration and biomass projections by component for each of three main regions separated by multivariate statistics and productivity curves. Mean annual carbon sequestration rates approach 3.90, 0.90, and 0.45 Mg ha^{-1} y^{-1} for reforested sites of the States of Durango, Nuevo Leon, and Coahuila, respectively. Native species of coniferous forests of Durango (P. durangensis, P. cooperii, and P. engelmannii) and Nuevo Leon (P. pseudostrobus) sequester carbon at higher rates than the introduced pine species of Durango (P. arizonica), Nuevo Leon (P. cembroides, P. pinceana, and P. nelsoni), and Coahuila (P. halepensis). Stands reforested are sequestered carbon at a higher rate than stands of native coniferous forests because of the largest plant density of the former sites, therefore they provide additional environmental benefits.

INTRODUCTION

Afforestation and reforestation practices are common practices in the upland sites of the Sierra Madre Occidental and Oriental mountain ranges of northern Mexico. For the period of 1993-1998, on the average, 3000 ha were reforested every year [*Semarnap*, 1999]. Regardless of this effort to restore plant cover, in northern Mexico there are currently extensive areas with low plant densities that require additional silvicultural treatments to improve stocking. Inegi [2001] reported that there are approximately 4 M ha in the states of Durango and Chihuahua with less than 60 m^3 ha^{-1} of standing volume. In particular the eastern slopes of the Western Sierra Madre mountain range are lacking natural regeneration and stocking is diminishing by human-related disturbances, including grazing practices and forest fires, as well as to potential subtle climatic changes. Landowners require economic incentives to promote reforestation practices to conserve and restore plant cover through sustainable forest management. The long-term economic and environmental benefits of these forestry activities may speed conservation efforts in the region. The emerging international greenhouse market and the payment for environmental services provided by the federal government of Mexico may provide economic incentives to fully restore plant cover of the Western Sierra Madre mountain range. However, studies dealing with carbon fluxes by reforestation practices are lacking in northern Mexico. In this study we address the carbon sequestration services provided by reforestation practices carried out in Durango, Mexico.

MATERIALS AND METHODS

This research was conducted in reforestation sites of the Sierras Madre Occidental and Oriental mountain ranges of northern Mexico. Reforestation sites of several community-based land ownership, *ejidos*, were sampled. The area is characterized by cold-temperate, temperate and arid climates in Durango, Nuevo Leon and Coahuila, respectively. Sample data consisted of selecting a random chronosequence of 124 quadrats (20 m x 20 m) reforested in Durango (38) with P. durangensis, P. cooperi, P. engelmanii, and P. arizonica; in Nuevo Leon (46) reforested with P. pseudostrobus, P. pinceana, P. cembroides, and Cupressus arizonica; and Coahuila (40) reforested with P. halepensis. In each reforested site, trees, litter, and necromass were inventoried and this information was sufficient to fit volume, biomass component, site index equations, and carbon sequestration rates. Biomass equations developed for this project were reported in *Navar et al.*, (2004). Biomass and carbon expansion factors were derived to compute carbon stocks from stand volume. A stand class model was fitted to project stand volume using basal area, site index, and age of forest plantations; and the theory behind the basal area and volume growth models is described in *Clutter* (1963) and *Clutter et al.* (1983).

RESULTS

Models to Project carbon sequestration by reforestation practices for each one of the Mexican States were developed, and example for the State of Durango is presented in Fig. 1. Trees of reforested sites sequester a mean annual carbon rate of 3.90, 0.90, and 0.45 Mg ha^{-1} y^{-1} for reforested sites of the states of Durango, Nuevo Leon, and Coahuila, respectively. The differential carbon sequestration rates are partially explained by the physical features of the environment. Native species of coniferous forests of Durango (P. durangensis, P. cooperii, and P. engelmannii) and Nuevo Leon (P. pseudostrobus) sequester carbon at higher rates than the introduced pine species of Durango (P. arizonica), Nuevo Leon (P. cembroides, P. pinceana, and P. nelsoni), and Coahuila (P. halepensis). Reforested sites provide additional environmental benefits since they sequester carbon at a larger rate than native coniferous forests. Using growth and yield models developed by Aguirre-Bravo (1987), understocked, native coniferous forests of central Durango sequester an average rate of approximately 0.90 Mg C ha^{-1} y^{-1}. High stand stocking and probably slightly higher growth rates in reforested sites appear to be important factors controlling the additional increment of carbon sequestration. Currently, mature forests are understocked, since *Navar et al.*, [2001] reported an average of 694 trees ha^{-1}, with average dbh of 26 cm for 1500 stands distributed in south central Durango, México.

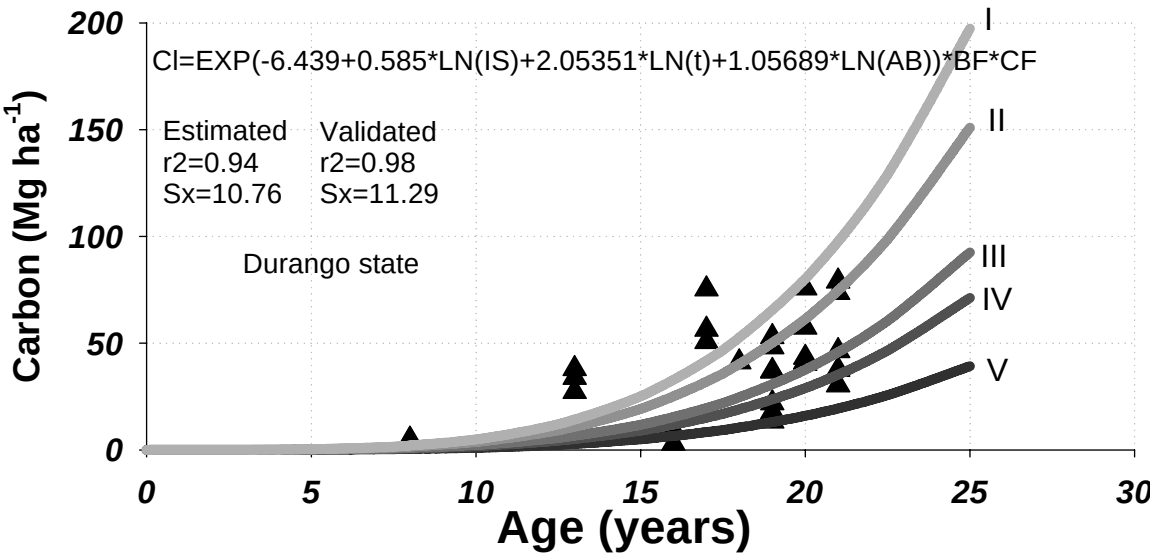

Fig. 1. The model to project carbon sequestration in reforested sites of the State of Durango, Mexico with fitting and validating statistics. CI = carbon stock (Mg ha-1), IS = site index (m at t=15 y), AB= basal area (m^2 ha^{-1}), BF = biomass expansion factor, CF = carbon expansion factor (0.50).

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