ABSTRACT

Global forests store 2.4 GtC/yr but climate warming and increase in precipitation can reduce their productivity and carbon sequestration potential. This study was designed to assess the current carbon stock and impact of predicted climatic warming and increase in precipitation on regulatory ecosystem services of the Hayat-ul-Mir (HM) subtropical scrub reserve forest, Soan Valley Pakistan. In the HM forest, tree dendrometric measurements of *Acacia modesta* and *Olea ferruginea* were taken in 47 survey plots (0.04 ha) and soil and leaf litter samples were collected from sub-plots of $1m^2$ to assess tree and forest floor carbon. The robustness of existing generic pantropical biomass allometric model of Chave et al. (2014) and i-Tree Eco tool was evaluated against local species specific volume allometric models. The satellite imagery was processed to assess spatio-temporal changes in the tree density of the HM forest during 2007, 2013 and 2019. The simulation for future land cover (year 2030) was done through CA-Markov model under business as usual scenario. The spatial land cover data of 2019 and 2030 and carbon pools data was processed in Integrated Valuation of Environmental Services and Tradeoffs (InVEST) carbon model to assess future carbon storage, sequestration and monetary benefits of the HM forest. The decomposition dynamics of mixed species leaf litter was investigated in the field (360 days) under ambient conditions. The short term effect (90 days) of predicted warming and (+2.3°C and +4.5°C) and increase in soil moisture ($M_{20\%}$) was investigated on decomposition of leaf litter in the laboratory microcosms. The seeds and seedlings of *A. modesta* and *O. ferruginea* were exposed to similar warming and soil moisture conditions in a plant growth chamber to assess changes in species growth rate and carbon storage potential.

Results showed that the HM forest stored 18.6 Mg/ha and 3.6 Mg/ha carbon in the tree biomass and in forest floor (soil and leaf litter) respectively. No significant difference was observed in the biomass carbon estimates (Mg/ha) made with local (8.53) and pantropical (8.68) models for *A. modesta.* The difference in the estimates for *O. ferruginea* (10.92, 11.91 and 11.87 for local allometric, pantropical model and i-Tree Eco, respectively) also remained insignificant. All allometric models fitted data well ($p < 0.001$). However, the pantropical model incorporating three biophysical variables better predicted biomass and was found more robust for both species. The

results revealed that in the absence of local models, the pantropical model can provide better biomass estimates for deciduous and evergreen subtropical species to report carbon stock. The land cover analysis showed increase in the tree density of *A. modesta* and *O. ferruginea* during baseline (2007-2019) and predicted (2030) time period. It is also expected that the total carbon stock of HM forest would increase from 23912 Mg (current) to 24024 Mg in future (2030) sequestering 112 Mg of carbon with net present value of $4112. The field decomposition of leaf litter was observed with ~48% of residual weight and 12% remaining carbon with gradually decreasing decay rate over time. Incubation time significantly affected decomposition rate but the effect of elevation remained insignificant although carbon and nitrogen mineralization was low at higher elevations ($E_{850\text{-}1020\ m}$) indicating their potential for long term carbon storage. Warming accelerated the pace of decomposition reducing litter half life by 77 days. Nitrogen and carbon mineralization was increased by 20% and 45% under interactive effect of warming and higher moisture ($M_{20\%}$) availability. There was a 40% increase in the rate of soil CO_2 efflux representing decrease in soil carbon accumulation. Seed germination was completely inhibited under warming (+4.5°C), however only few seeds (50%) of *A. modesta* germinated and survived (67%) at +2.3°C warming and $M_{20\%}$. Warming (+4.5°C) induced detrimental effects on both species. Warming of +2.3°C and $M_{20\%}$ was beneficial for *O. ferruginea* and increased its overall growth and biomass carbon accumulation (4.3 g) compared to control (3.2 g). However *A. modesta* only grew better under ambient condition. These findings suggest that although HM forest is currently storing 22.3 Mg/ha carbon but warm and wetter future will reduce its soil carbon stock. It might also induce shifts in the productivity and provision of ecosystem services by co-occurring species of the HM forest. Future rise of 2.3°C in mean temperature could be ecologically significant to cause changes in the ecosystem structure by favoring the growth of *O. ferruginea* and restricting the growth of *A. modesta*. The study recommends taking proactive measures to enhance the carbon sequestration potential by increasing tree density and restricting anthropogenic activities in the forest.