A scientific framework for forecasting carbon sequestration in rangelands

C Dean and R J Harper
Forest Products Commission, 117 Great Eastern Highway, Rivervale, WA 6103, Australia, E-mail: christopher.dean@fpc.wa.gov.au

Introduction The uncertainty (higher for more arid areas) of the worth of rangelands for carbon sequestration (CS) can be determined from the vast range of existing and seemingly conflicting scientific work by identifying and assembling the basic components to form pragmatic and comprehensive CS forecasting. For the last 50,000 years people have burned or cleared forests and woodlands to favour large herbivores, and more recently to produce food, lumber, urbanisation, paper and vehicle fuel. The net effect of aerobically decomposing woody matter (e.g. cellulose), whether via direct combustion, burning of fossil fuels or oxidation of soil carbon following erosion is, in chemical terms, the reaction:

$$(n(C_6H_{10}O_5)) + 6nO_2 \longrightarrow 6nCO_2\uparrow + 5nH_2O + energy\ .$$

Vegetation-based CS projects aim to ameliorate our carbon-flux imbalance using 1) the reverse of the above equation (via photosynthesis), and 2) storage of vegetation decay products as soil carbon. Also, existing forests and woodlands *per se* have recently gained more recognition as ideal carbon stores. We examine the potential for CS in the 3.84 Mkm^2 occupied by the rangeland grazing industry in Australia—predominantly shrubland and woodland—i.e. a good candidate for long-term carbon storage. Land degradation (e.g. severe erosion, woody thickening, and accentuation of drought effects) has followed overuse and clearing by the advancing livestock industry for over a century. It also causes increased carbon emissions and decreased biodiversity (e.g. Walker and Steffen, 1993), and animal welfare legislation is inapplicable. Gleeson and Dalley (2006) noticed generally a focus on short-term productivity goals, opposition to environmental concerns, bureaucratic stagnation and paltry adjustments. The economics of climate change may provide impetus for change, e.g. via the Kyoto Protocol which allows for emissions to be offset by trading.

Materials and methods This paper represents a preview of a scientific literature review plus excerpts from fieldwork, and analyses of existing and new datasets including remote sensing and GIS methods—to be published separately. The events constituting carbon emission and sequestration can be simulated using superimposed sigmoidal curves, common in ecological studies. Processing temporal LANDSAT imagery for vegetative cover yields the expanse and magnitude of degradation. The degradation GIS layer combined with layers of biomass and soil carbon permits assignment of sigmoidal curves for each pixel from which regional forecasts are tallied. Uncertainties in measurement arise from unmeasured hydrological carbon and the need for 3D biomass data (e.g. from LIDAR or radar).

Results Some critical requisites for unequivocal results were found to be: allow between 30 and 500 yrs in semi-arid and arid areas for measurable changes in C; use environmentally and edaphically paired sites; accommodate high spatial variability in soil organic carbon (SOC)—positively correlated with woody biomass; record shrub/tree decline and forestry activities; measure SOC to at least root depth—deeper in coarser soils and dryer areas; and notably: percentage changes in carbon stocks elucidate phenomena rather than comparison of absolute values. Estimated C emission rates resulting from current management are 4 to 60 $Mt\text{-}C.yr^{-1}$ and for SOC: 0.7% $.yr^{-1}$-similar in magnitude to those overseas. Estimates of CS for woody thickening are in the order of 0.4 $t\text{-}C.ha^{-1}.yr^{-1}$ but its extent remains undetermined. Exclusion of livestock can increase carbon stocks several fold in degraded areas, estimates for CS upon destocking range from 4 to 25 $Mt\text{-}C.yr^{-1}$. We estimate CS at ~1% $.yr^{-1}$, i.e. 6 $Mt\text{-}C.yr^{-1}$, or ~300 Mt-C over 50 yrs. This value is halved if the Chicago Climate Exchange limit of areas with more than 356 mm rainfall is imposed. An uncertain prognosis for CS arises significantly from: 1) invading buffel grass (*Cenchrus ciliaris*) which can dehydrate shrubs and increase burning, 2) climate change with increased scarcity and intensity of rainfall—inducing more fires and erosion, and 3) population growth.

Conclusions The potential CS of ~300 Mt-C upon destocking is not large compared with our global carbon-flux imbalance but there are corollary benefits such as halting the current rangeland emissions. Uncertainties remain at two levels: 1) precision of the CS values, and 2) achieving the CS by a change in management paradigm.

References

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