Agriculture, Ecosystems and Environment 223 (2016) 108–114

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Carbon sequestration potentials of semi-arid rangelands under traditional management practices in Borana, Southern Ethiopia

Negasa Gilo Bikila[a,*], Zewdu Kelkay Tessema[b], Ebro Gedda Abule[c]

[a] Yabello Pastoral and Dryland Agriculture Research Center, PO Box 85, Yabello, Ethiopia
[b] School of Animal and Range Sciences, College of Agriculture and Environmental Sciences, Haramaya University, PO Box 138, Dire Dawa, Ethiopia
[c] International Livestock Research Institute, PO Box 5689, Addis Ababa, Ethiopia

ARTICLE INFO

Article history:
Received 24 August 2015
Received in revised form 20 February 2016
Accepted 22 February 2016
Available online 5 March 2016

Keywords:
Aboveground carbon stock
Belowground carbon stock
Rangeland management
Semi-arid areas
Soil attributes

ABSTRACT

A study to determine carbon sequestration potentials and soil attributes was conducted in Borana rangelands of southern Ethiopia under communally grazed areas, grazing enclosures (rangelands enclosed for 20 years for dry season grazing) and rangelands managed by prescribed fire for more than five years after fire application. Soil attributes were collected from three soil depths (0–10 cm, 10–20 cm and 20–30 cm) and both aboveground and belowground carbon were estimated in all treatments. Belowground carbon stocks were higher than the aboveground carbon stocks in all management systems in Borana rangelands. Tree and shrub carbon and soil organic carbon stocks were higher ($P < 0.01$) in rangelands enclosed for 20 years than other rangeland management systems, whereas grass carbon stocks was higher ($P < 0.05$) in rangelands managed by prescribed fire. Total carbon stock was higher ($P < 0.01$) in enclosed rangeland areas (300.4 t C ha^{-1}) than in rangelands managed by prescribed fire (184.9 t C ha^{-1}) and in communally grazed areas (141.5 t C ha^{-1}). Therefore, rangelands enclosed for more than 20 years for dry season grazing and rangelands managed by prescribed fire had good carbon sequestration potentials both in the soils and aboveground vegetation. Consequently, pastoralists land management can be an important source for sequestering carbon to offset carbon emissions as mitigation of climate change.

1. Introduction

Rangelands play a significant role in the mitigation of climate change as they occupy about half of the world's land mass (Friedel et al., 2000). Accordingly, the management of rangelands can be used for the mitigation of climate change and rising atmospheric carbon dioxide concentrations since they store huge amount of carbon both in the aboveground vegetation and soils (Derner and Schuman, 2007). Rangelands are estimated to store more than 30% of the world's soil carbon in addition to the substantial amount of above-ground carbon stored in trees, bushes, shrubs and grasses at the natural state or moderately disturbed by grazing (IPCC (Intergovernmental Panel on Climate Change), 2007; Vashun and Jayakumar, 2012). However, it has been suggested that under traditional land use management, overgrazing leads to loss of carbon stocks (Tessema et al., 2011). Many rangeland management techniques such as rehabilitation and grazing enclosures are intended to increase forage production and have the potential to sequester atmospheric carbon both in soils and aboveground vegetation (Homann et al., 2008). Various rangeland management practices are believed to increase carbon stocks in soil by an average of 0.35–3 t C ha^{-1} yr^{-1} (FAO (Food and Agriculture Organization), 2010). Accordingly, prescribed rangeland burning and seasonal grazing enclosures and controlling bush encroachment (Gemedo et al., 2005) would increase carbon sequestration potentials of semi-arid rangeland ecosystem (Bradd Witt et al., 2011). In semi-arid rangeland ecosystems, soil carbon sequestration may initially increase with bush encroachment, but it may decline when bush densities become high enough to inhibit growth of the understory grass (Hudak et al., 2003). Soil carbon levels are linked to rates of decomposition, plant production understory and plant litter inputs into the soil system. However, application of subsequent and repeated fires may actually volatilize the soil carbon before it can be successfully incorporated into the soil carbon pools (Rovira et al., 2009; Nolan, 2012). In this study, the possibilities of increasing carbon stocks through traditional management systems in Borana rangelands of southern Ethiopia are investigated.

Traditionally, the Borana pastoralists classify their rangelands into *Kalo, Warra* and *Foora* land use units. *Kalo* is grazing enclosure

* Corresponding author. Fax.: +251 464460663.
E-mail addresses: binagi2009@gmail.com, bikole1985@gmail.com (N.G. Bikila).

http://dx.doi.org/10.1016/j.agee.2016.02.028
0167-8809/

made by fencing the communally grazing areas using thorny bushes or shrubs for fodder bank development by pastoral communities kept for grazing during the long dry season. The Fo*ora* rangeland units are grazing areas kept for herds that include dry cows, oxen, bulls, immature males, and heifers, whereas the *Warra* rangeland units are grazing areas kept for herds that consist of milking cows, emaciated animals, sick animals and calves that cannot walk long distances in search of feed and water. *Foora* and *Warra* are classified under communal grazing areas. Whenever the *Foora* and *Warra* rangeland units are encroached by bushes, pastoralists use fire to control bush encroachment, tick infestation and to improve the growth and palatability of the grass and herbaceous vegetation for their livestock. Although many studies have been conducted in Borana rangelands on vegetation structure (Coppock, 1994; Gemedo et al., 2005; Angasa, 2007; Homann et al., 2008; Samuel, 2009; Bikila et al., 2014), information on carbon sequestration potentials under different rangeland management practices are non-existent. Besides, there are no studies with direct focus on estimating carbon stocks both in the aboveground and belowground soil profile under different rangeland management practices. Hence, this study was designed to determine carbon sequestration potentials of three traditional rangeland management practices: (a) rangelands enclosed for about 20 years as dry season grazing, (b) rangelands managed by prescribed fire for more than five years after fire application and (c) communally owned grazing areas in aboveground vegetation and soils. Therefore, the objectives of this study were to investigate aboveground and belowground carbon stocks across traditional rangeland management practices and along soil depths in Borana rangelands of southern Ethiopia, a typical of semi-arid ecosystems in eastern Africa.

2. Materials and methods

2.1. Descriptions of the study area

This study was carried out in Yabello district of Borana zone, southern Ethiopia. Yabello district was selected for this study because it is an area wherein different traditional rangeland management practices are applied (Fig. 1). The area's landscape is slightly undulating that ranges in altitude from 1000 to 1500 m above sea level, though landscape has picks that range up to 2000 m above sea level.

The main soils of the region comprise 53% red sandy loam soil, 30% black clay and volcanic light colored silty clay and 17% silt and vertisols (Angasa, 2007). The rainfall of the area is distinctly of a bimodal pattern, viz-a-viz. the main rainy season locally called *Ganna* which accounts for 59% of the total rainfall of the area, occurring from March to May and the short and small rainy season locally called *Hagayya,* which accounts for 27% of the total rainfall of the study area, and it occurs from end of September to November. A prominent feature of the Borana rangeland including the Yabello district is the erratic and variable nature of the rainfall, with most areas receiving between 238 mm and 896 mm of rain annually (Angasa, 2007).

2.2. Site selection and field layout

The three traditional rangeland management practices used for this study were rangelands enclosed for 20 years for dry season grazing reserves or standing hay making locally called *Kalo* or grazing enclosures, rangelands managed by prescribed fire for five years after fire application and communally grazed rangeland areas. In order to establish permanent plots and avoid bias,

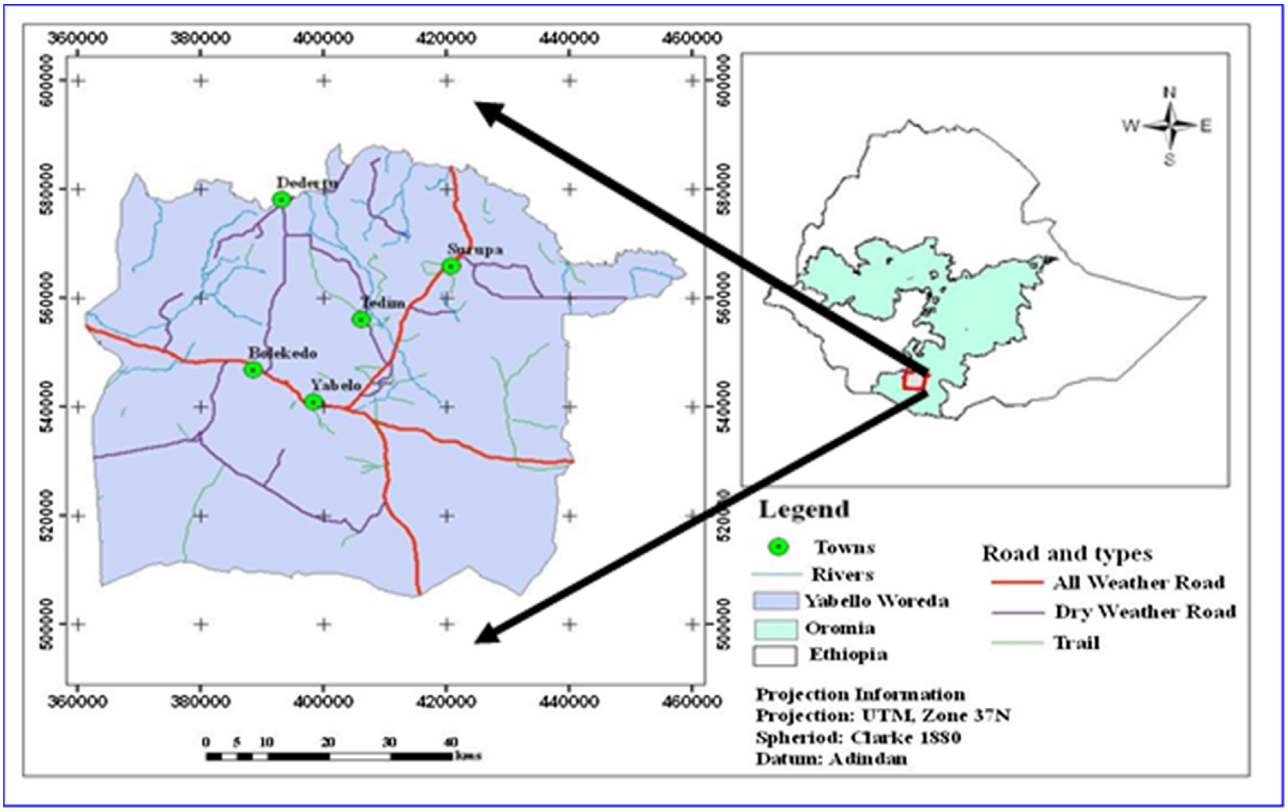

Fig. 1. Map of the study area, Yabello district of Borana rangelands, southern Ethiopia.