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Carbon stock accumulation in Pinus kesiya forests in south-western Yunnan, China, under the Grain for Green Programme

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Introduction

Reforestation and afforestation are two effective ways to mitigate the impacts of climate change and increase global carbon stocks. However, the land-based potential of afforestation/reforestation to remove significant amounts of greenhouse gases from the atmosphere has not yet been determined. Therefore, it is crucial to estimate the carbon stocks deriving from afforestation/reforestation.

China's Grain for Green Programme (GFGP), launched in 1999, is the largest ecological restoration program in the world. Implementation of GFGP has reduced soil erosion and increased vegetation cover, and has also improved ecosystem services, e.g., carbon sequestration, flood mitigation, sandstorm prevention, water retention, and food production. However, GFGP is also creating challenges for habitat quality, by planting alien tree or monoculture species on farmland, and the lower carbon stocks in secondary forest regrowth following such activities is unknown.

Objectives

Specific objectives were to: (1) map the distribution of Pinus kesiya forest since implementation of GFGP (1999); (2) conduct a field survey to determine carbon density changes in Pinus kesiya forest with increasing forest age; and (3) combine data on forest age of Pinus kesiya planted under GFGP, inferred using GIS technology, with data on Pinus kesiya forest distribution to estimate carbon stock accumulation in Pinus kesiya forest since GFGP.

Methods

1. Mapping Pinus kesiya forest We acquired Landsat images and GDEMV2 data with 30 m spatial resolution from the USGS website (https://glovis.usgs.gov/) in SW Yunnan (Figure 1). ENVI 5.3 was used classified into six land use types (natural forest, coniferous forest, economical forest, shrubland, farmland, construction land, and water), using the maximum likelihood classification algorithm. Field survey data and visual interpretation were used to evaluate the accuracy of the land use maps. The Kappa coefficient of the land use maps for 1999, 2009, and 2016 was 0.84, 0.87, and 0.88, respectively.

2. Carbon density of Pinus kesiya forest A total of 44 Pinus kesiya forest plots of different ages in the prefectures of Puer and Lincang were sampled. The size of each forest plot was 20 m × 50 m. Diameter at breast height (DBH) and species was determined for every tree per plot with DBH > 5 cm. A total of 17 standard Pinus kesiya trees of different ages were selected to estimate the form of the power function. We measured the fresh weight of tree components for each standard tree, weighed portions of fresh tree components, and brought samples to the laboratory to determine dry weight. We used fresh weight and dry weight of tree components to calculate tree component biomass ratio.

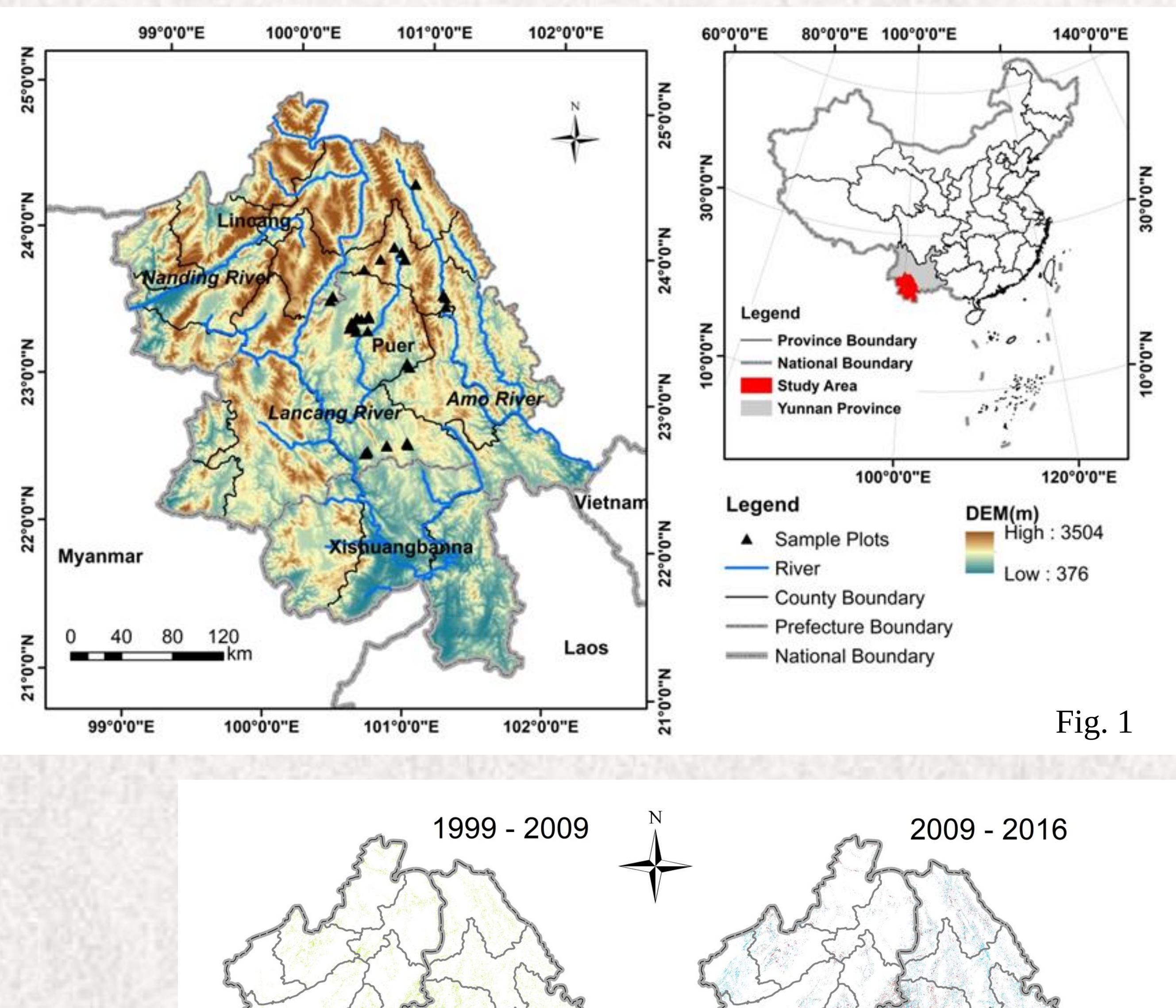

Fig. 1

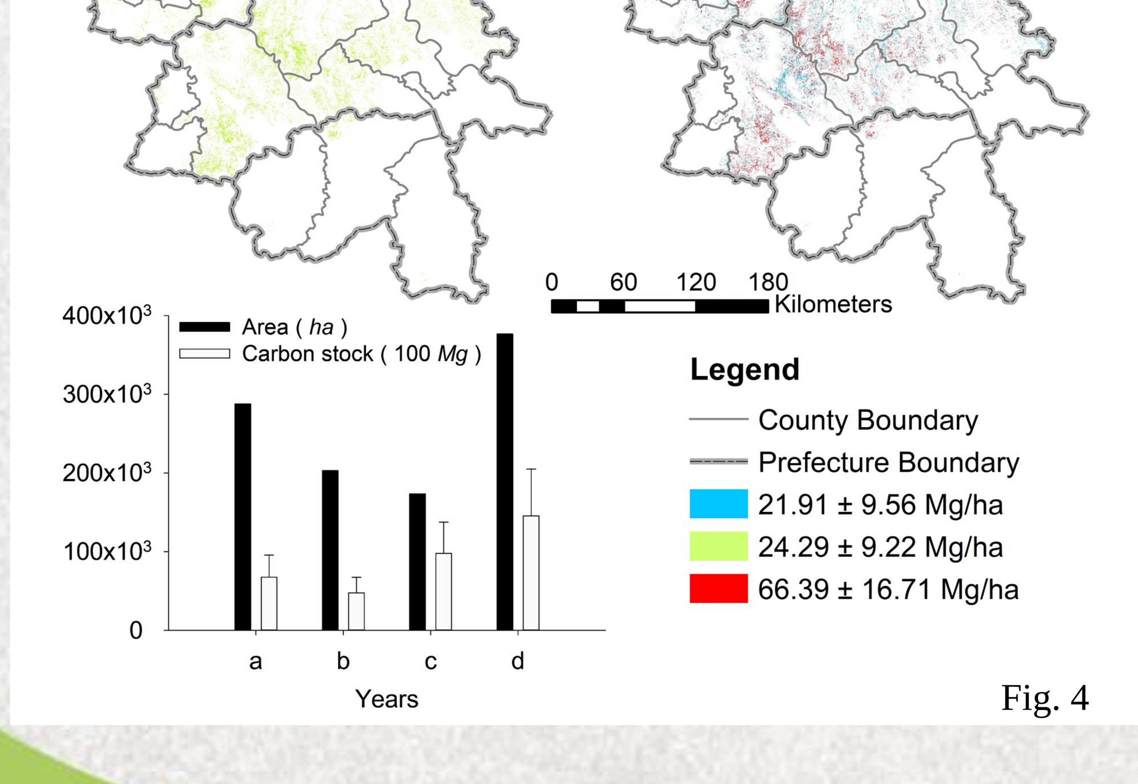

Fig. 4

Results

1.Pinus kesiya forest area showed an increasing trend after implementation of GFGP (Figure 2). During the period 1999-2009, shrubland was the major land type transformed to Pinus kesiya forests and other forests, the area of which increased by 3050.93 km^2 and 1742.12 km^2 , respectively. During the period 2009-2016, shrubland and farmland were the major land types transformed to Pinus kesiya forests and other forests, with the area increasing by 521.27 km^2 and 2018.64 km^2 , respectively.

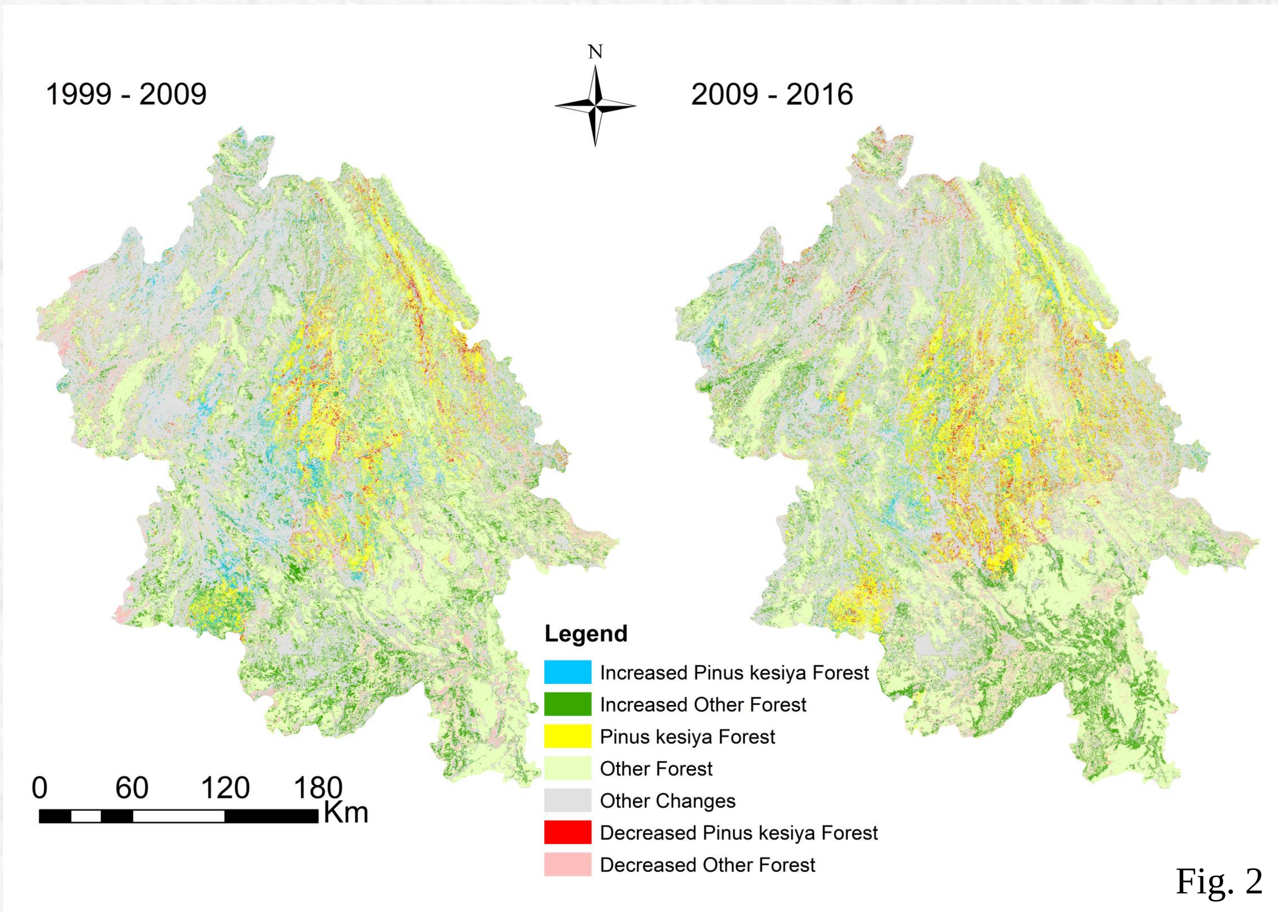

Fig. 2

2. The carbon density of Pinus kesiya forest showed an increasing trend with forest age (p < 0.01) and increased by 4.24 Mg per hectare and year (Figure 3). The tree layer and the litter layer both showed an increasing trend in carbon density, while that of the shrub layer (p = 0.0696) and the herbage layer (p < 0.01) layer decreased significantly with forest age.

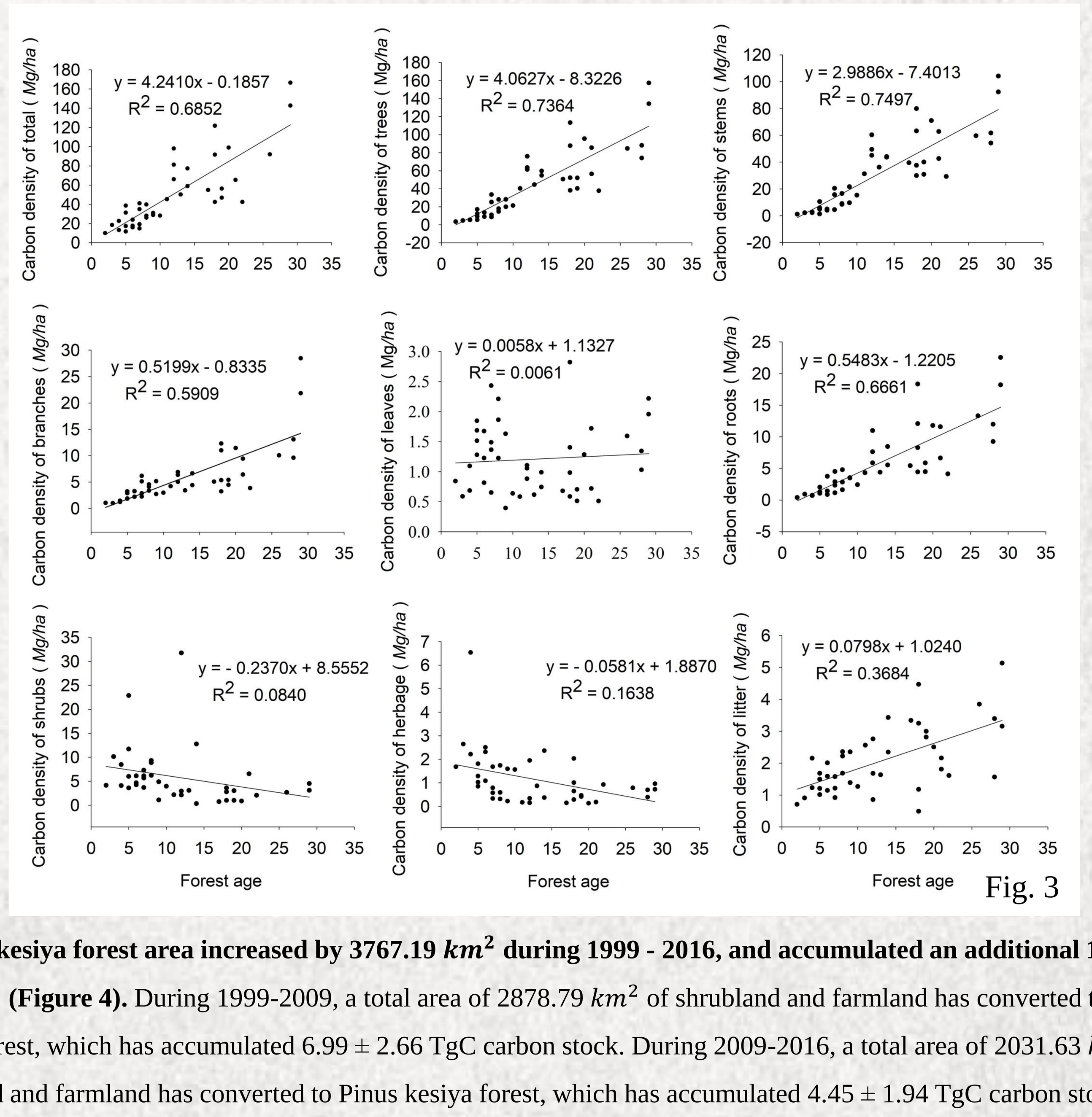

Fig. 3

3. Pinus kesiya forest area increased by 3767.19 km^2 during 1999 - 2016, and accumulated an additional 15.97 ± 4.84 TgC (Figure 4). During 1999-2009, a total area of 2878.79 km^2 of shrubland and farmland has converted to Pinus kesiya forest, which has accumulated 6.99 ± 2.66 TgC carbon stock. During 2009-2016, a total area of 2031.63 km^2 shrubland and farmland has converted to Pinus kesiya forest, which has accumulated 4.45 ± 1.94 TgC carbon stock, with an additional 11.52±2.90 TgC accumulated from the growth of 1735.57 km2 planted during 1999 - 2009. Therefore, the Pinus kesiya forest has accumulated 15.97 ± 4.84 TgC during 2009-2016.

Conclusions

The results suggested that implementation of GFGP increased the area and carbon stocks of Pinus kesiya forest in the region. The carbon stock is also expected to increase with increasing forest age. Our method of combining remote sensing methods and GIS-based spatial analysis to derive forest distribution, age, and area should lead to higher accuracy in estimation of carbon stocks. However, the carbon density of Pinus kesiya forest in SW Yunnan is lower than in other countries, possibly due to regional climate conditions and human activities.

RESEARCH PROGRAM ON Forests, Trees and Agroforestry