The Chinese Grain for Green Program – assessing the sequestered carbon from the land reform

Madelene Ostwald[1,2,*], Jesper Moberg[2], Martin Persson[2], Jintao Xu[3]

[1]*Centre for Climate Science and Policy Research, Department of Water and Environmental Studies, Linköping University, Norrköping, Sweden*
[2] *Physical Resource Theory, Department of Energy and Environment, Chalmers University of Technology, Göteborg, Sweden*
[3]*College of Environmental Science and Engineering, Peking Universit, Beijing, China*
**Corresponding author. Tel: +46 11363292, Fax: +46 11363292, Email: madelene.ostwald@liu.se*

Abstract: Grain for Green Program was launched in China as a national measure to control erosion and increase vegetation cover in 1999. With a budget of 40 billion US dollar, the program that targets cropland and barren land has today converted over 20 million hectares of land into primarily tree-based plantations. Even though the design of the program includes a category of energy forest only a negligible part is planted as such (0.61%). The majority of the land converted is for protection (78%). The use of these plantations in the future is however unclear and a hypothesis of energy substitution is valid.
In this paper, we try to estimate the overall carbon that has been sequestered due to the program by using official statistics from the program and by calculating it according to mainly three different approaches; calculations made on I) net primary production, II) figures from IPCC's greenhouse gas inventory guidelines, and III) mean annual increment. We also highlight several of the uncertainties that are associated with the program and the estimations.
The result shows that conversion of cropland and barren land generated carbon sequestration over its 10 first years ranging from 222 to 468 million tonnes of carbon, with the IPCC approach yielding the highest estimate whereas the other two approaches had more similar outcome (around 250 million tonnes of carbon). Uncertainties associated with the assessment lies within the use of growth curves not designed for the particular species and their different locations, actual survival rate of the plantations, and discrepancies in figures concerning the program (e.g. area, type, survival rates) at different levels of authority (from national to local). The carbon sequestered in the biomass (above and below ground) from this program is equivalent to 14% (based on median of all three approaches) of China's yearly carbon dioxide emissions due to fossil fuel use and cement production.

Keywords: *Land-use change, Mitigations impact, Plantations, Carbon sink, Bioenergy.*

1. Introduction

As China continues its rapid rate of development, dealing with the massive and growing emissions of greenhouse gases (GHG) (6.5 mega tones of carbon dioxide (tCO2) in 2007 corresponding to 22% of the global total) the country will be vital in the context of global climate change [1]. Afforestation and reforestation have become important measures in China to slow down the wind and water erosion. In 1999 the Chinese government introduced the Grain for Green Program (GGP) also known as Slope Land Conversion Program [2] or The Conversion of Cropland to Forest and Grassland Program [3]. The large-scale afforestation under the GGP will result in a large amount of new forest and hence enhance the carbon sequestration capacity in the terrestrial ecosystems. With this quick background setting the objectives of the paper are to i) estimate how much carbon the program has sequestered, ii) how a national assessment can be conducted and the potential strengths and weaknesses it holds, and finally iii) what the potentials are to use the biomass produced as an energy substitute for fossil-fuel.

2. The program and the setting

The GGP feature the conversion of steep-sloped and degraded cropland and barren land to forest and grassland by millions of small landholders in 25 provinces, municipalities and

autonomous regions (Fig. 1). The primary targeted area of the GGP was the basins of the Yellow and Yangtze River. The Loess plateau located in the upper and middle reaches of the Yellow River is a part of this area. It is well known for severe soil erosion and degraded land. Over 60% of the land suffers from various degrees of soil erosion as a consequence of unsustainable use and degraded vegetation cover, as well as the presence of deep, loose yellow soils [4]. The GGP mainly focuses on steep slopes that seriously threaten to degrade the water quality in the rivers.

Figure 1.Grain for Green Program coverage in China (yellow) indicating the sensitive areas around the Yellow River and Yangtze River.

3. Methods and materials

To estimate the carbon in the trees planted under the GGP information on area, location of plantation and the locations physical characteristics, species, increment per year and survival rate were needed and collected from forestry statistics and national and province level and scientific literature. To estimate the carbon sequestration performance of the programme we assumed a baseline of what plausible would happen in the absence of the implementation. Due to the targeted soils' degraded character with high erosion and unsustainable agriculture we assume the carbon sequestration would be equal to zero of negative. The carbon pools included in the calculation was above and below ground biomass with the latter as a ratio of 0.26 of the former [5].

The total carbon stock for the different regions, i.e. provinces, is calculated according to equation 1:

$$C_{Total} = \sum_{j}\left[\sum_{i}(A_{i,j} \times C_{j} \times (Y - i))\right] \qquad \text{Equation 1}$$

where $A_{i,j}$ (ha) is the converted cropland for region *j* in year *i*. *Y* is the year the study was conducted, i.e. 2009. This means that the trees planted in year i=2008 has been growing for 1 year. C_j (tonnes carbon (ha yr)$^{-1}$) is the carbon increment per hectare and year fitted for the climate conditions of each for region *j*. The time frame used is from 1999 to 2008/2009. The amount of land converted is presented in Fig. 2.

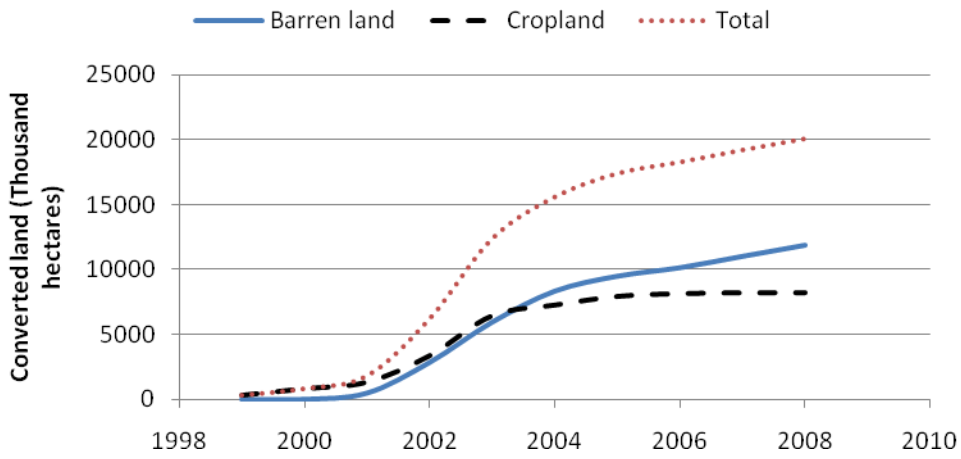

Fig 2. Total accumulated converted cropland and barrenland area 1999-2008, data missing for barren land 1999-2000 (Administration 1999-2008).

Three different values were used to assess the carbon in the terrestrial vegetation in GGP. 1) Net Primary Productivity (NPP), 2) Intergovernmental panel on climate change (IPCC) Guidelines for National Greenhouse Gas Inventories (GNGGI) and, 3) mean annual increment (MAI). Two of the NPP values were derived from China specific studies [6], [7] and one on global average [8]. IPCC default values i.e. in the lower accuracy level Tier 1, were used for natural and managed forest [9]. MAI values are primarily derived from a national assessment [10] or when missing a global value of 1.6 tC/ha/yr [11] was used.

4. Results

4.1. Carbon sequestered under GGP

The total area of barren land converted is larger than the area of cropland converted. Because of this the result of carbon sequestrated by barren land conversion is also larger as can be seen in Fig. 3. The highest value for cropland and barren land conversion is 468 million tonnes carbon (MtC) and the lowest value is 222 MtC. There is a large difference, 246 MtC, between the highest and the lowest values.

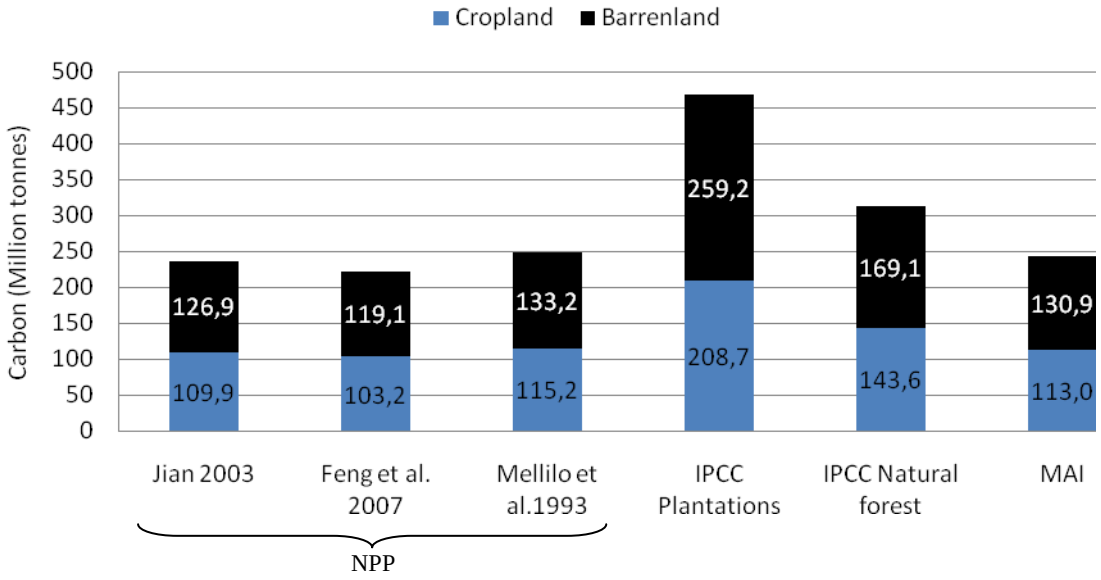

Fig 3. Total amount of carbon sequestrated by conversion of cropland under the GGP 1999-2008 (tonnes).

The reason behind the high value of the IPCC plantation figure can be that the default values are assessed for heavily managed systems including rotation.

4.2. Saptial differences in carbon from GGP

In most provinces the carbon sequestration under barren land and cropland is almost equally large, barren land being a little larger (Fig. 4). Only Xinjiang, Qinghai, Shaanxi, Sichuan and Jilin have larger carbon sequestration through cropland conversion than through barren land. Sichuan has the largest value, 31.7 MtC while Tibet has the lowest, 209 thousand tC.

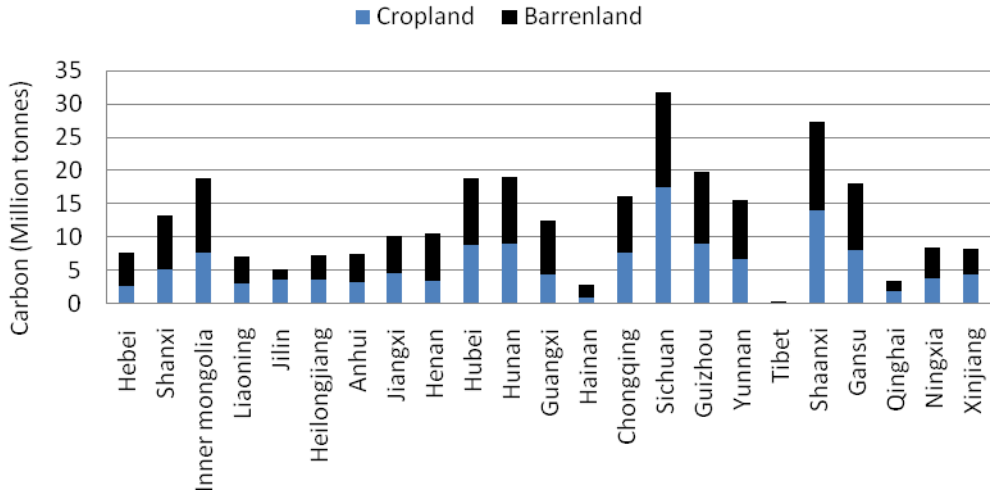

Fig 4. Average amount of carbon sequestrated by conversion of cropland 46.4% and barren land 53.6% under the GGP 1999-2008 per province (Million tonnes).

4.3. Sequestration level and potential impacts

From this 20 Mha plantation program the sequestering rate has been ranging from 222 to 470 MtC with a median on 246 MtC. This would mean that the annual sequestration range from 22-47 MtC/yr with a median on 25 MtC. Or if taken on a hectare basis, a carbon content of

11-23 tC/ha, which indicates a low productivity. Taking the median of 246 MtC it corresponds to 14% of the carbon emitted only in the year of 2009.

5. Discussion

There are large differences in figures depending on the biomass growth used in the model; differing up to 103%. This is due to assumptions on regional differences, species growth patterns and management impacts. Further, the different species and place of planting is crucial for the outcome. Also, the actual area that has been converted differs between sources ranging from 20 to 32 Mha, where we have chosen the lower value from the China forestry yearbook.

Since the legislation behind the GGP states that the forest planted may not be harvested until over-matured there are low potential to grow fast rotational energy forests on the land converted by the GGP. Further, the legislations defines only 0.61% of the forest planted as 'energy forest' whereas as much as 78% of the forest planted are for protection and most of these species are not suitable for usage as bio-energy. Hence, the potential for bio.energy for the forest planted within GGP is low. This is further evident when looking at the amount sequestered carbon that is fairly low, ranging from 11-23 tC/ha .

In order to make the estimation more accurate it would be interesting to collect province specific data regarding the species used and province specific biomass growth rate for all provinces. This would make the estimation more accurate since biomass growth is strongly dependent on local factors such as soil quality, thinning, irrigation and fertilization.

Another way to obtain more accurate results would be to divide the converted land into smaller areas that has a homogenous climate. By doing so better approximations of the biomass growth rates could be obtained by relating the growth rate to the climate.

6. Conclusion

- The carbon sequestrated by the conversion of cropland and barren land under the GGP ranges between 222.3 and 467.9 MtC. The median is 246 MtC while the mean is 289 MtC. With IPCC's approach for natural forests the amount of carbon sequestrated by the conversion of cropland and barren land between 1999-2009 is 312 MtC.

- 246 MtC sequestrated between 1999-2009 corresponds to 14% of the total carbon emitted from Chinas carbon emitted in one year (2009).

- The potential for bio-energy from the forest planted due to the Grain for Green program is low since the part of trees planted that are suitable for bio-energy is low and since the legislations prevents harvesting of the forest until over mature.

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