

POTENTIAL FOR ATMOSPHERIC CARBON CAPTURE IN ARID AND SEMI-ARID LAND SYSTEMS IN THE WESTERN REGION AND ITS GLOBAL SIGNIFICANCE

A. BACKGROUND

1. Climate change poses a major threat to human populations and to natural systems. It has been linked to changes in physical and biological systems, including accelerated glacier retreat, sea level rise and the timing of seasonal occurrences such as the flowering of trees. Future predicted changes are more extensive. The Gobi is predicted to transform to warm temperate desert scrub, and midland parts of central Asia are likely to change gradually into a more arid interior desert as the disappearance of mountain glaciers reduces the volume of water runoff in summer¹. In north-western China, wind storm frequency is expected to increase under global warming because of drier and stronger-wind conditions, resulting in accelerated soil degradation and increased dust storms. All of these phenomena are expected to have serious implications for agricultural production, availability of water and biodiversity in the western region as well as human health and welfare.

2. There are significant atmospheric carbon capture opportunities within land use², land use change and forestry (LULUCF) sectors in the western region that provide multiple social, economic and environmental benefits, including addressing land degradation issues. These can broadly be described as:

- (i) Improved agricultural land management, such as conservation tillage, soil conservation, grazing and fire management;
- (ii) Protection and enhancement of natural forest to prevent further losses of forest carbon stock; and
- (iii) Targeted afforestation and reforestation of ecologically suitable land and the continued incorporation of agroforestry into agricultural landscapes.

3. It is estimated that the foregoing opportunities can provide a significant carbon offset, with improved agricultural land management having the potential to contribute 25.7 Mt (million tonnes) of carbon storage per year by 2012; the forestry sector has the potential to capture approximately 87 Mt carbon up to 2012. However, carbon capture in the western region should be considered as being a significant additional benefit that can be achieved while addressing land degradation and should not be targeted in isolation. For example, large scale tree planting across the extensive arid and semi arid areas, where extensive irrigation using scarce water resources is required to ensure tree survival and growth, is not sustainable in the long term and may, in fact, result in broader negative impacts. In these localities, protection of remnant indigenous vegetation and forests, rehabilitation of indigenous ecosystems (particularly grasslands), limiting agricultural production to areas where sustainable management can be achieved, and improving agricultural land management should be considered as priorities.

4. The western region covers 6.82 million km² and makes up 71 percent of the total land area of China. Land degradation occurs in 43% of the region, with severe desertification and land degradation mainly occurring in the provinces/autonomous regions of Xinjiang Uygur, Inner Mongolia, Sha'anxi, Gansu, Ningxia and Qinghai. Increasing land reclamation for cropping and grazing and increasing livestock numbers are believed to be the cause of much of the land degradation in these areas.

¹ Watson *et al.* 1997. *Regional Impacts of Climate Change: An Assessment of Vulnerability*. A Special Report of the IPCC Working Group II.

² For ease of understanding and translation into the Chinese Language, the term 'carbon capture' is used in this appendix in place of 'carbon sequestration'.

5. Grasslands cover 40 percent of PRC's area, the most important being in Inner Mongolia, Xinjiang and Qinghai. Many of them have been severely degraded by conversion to cropland and through overgrazing as a result of market-driven policies aimed at increasing agricultural productivity. This has come at a cost to traditional communities, who comprise some of the poorest groups in China, and whose livelihood has been severely affected by the declining health and productivity of grasslands.

6. Following the dramatic increase in grassland degradation since the 1980s, the government now recognizes the wider ecological benefits of grasslands, and has translated this recognition into policies that focus on the establishment of artificial grasslands, landscape protection and rehabilitation. However, there are still major problems. There is a high administrative cost associated with managing and monitoring private land tenure relative to the low productivity of grassland. Also, most grassland research still focuses on livestock productivity rather upon the need for protection of grassland ecosystems and of ecologically sustainable livestock production³.

B. CARBON CAPTURE POTENTIAL OF THE WESTERN REGION

7. The extensive land area in the western region (6.82 million km²) indicates that there is a large potential for carbon capture and storage. A broad assessment of the carbon capture potential under the key areas of (i) agricultural land management, and (ii) afforestation and reforestation, is reviewed in this section based upon an extrapolation of information derived from international literature, available information about land degradation in western China and assumptions of the application of improved land management practices over the coming decades and of carbon capture data. Carbon capture activities that are appropriate for the western region are shown in Table 4.1.

Table 4.1: Activities to Increase Carbon Capture and Storage in Agriculture and Forestry

Agricultural Management ⁴ (adapted from Pretty <i>et al</i> , 2002)
<ul style="list-style-type: none"> • replace inversion ploughing with conservation- and zero-tillage systems; • adopt mixed rotations with cover crops and green manures to increase biomass additions to soil; • adopt agroforestry in cropping systems (such as shelter belts) to increase above-ground standing biomass; • minimize summer fallows and periods with no ground cover to maintain soil organic matter stocks; • use soil conservation measures to avoid soil erosion and loss of soil organic matter; • apply composts and manures to increase soil organic matter stocks; • improve grazing, vegetation and fire management of pastures and grazed grasslands to reduce degradation and increase soil organic matter; • cultivate perennial grasses (60-80 percent of biomass below ground) rather than annuals (20 percent below ground); • restore and protect agricultural wetlands; • convert marginal agricultural land to grassland and woodlands.
Forest Management
<ul style="list-style-type: none"> • minimize forest degradation and harvesting • afforestation and reforestation

1. Potential for Carbon Capture through Agricultural Land Management

8. In the absence of specific information on the carbon capture potential in western PRC, time-averaged rates of carbon storage from international literature have been used (Table 4.2⁵).

³ World Bank. 2001. *China: Air, Land and Water – Environmental Priorities for a New Millennium*, Washington DC.

⁴ Adapted from Pretty *et al*, 'The Role of Sustainable Agriculture and Renewable Resource Management in Reducing Greenhouse Gas Emissions and Increasing Sinks in China and India'.

⁵ Watson *et al*. 2000. IPCC Special Report on Land Use, Land-Use Change and Forestry.

The carbon storage potential that can be achieved through improved land management may be estimated by multiplying carbon capture rates by land area and an estimated rate of adoption.

Table 4.2: Estimates of Carbon Storage Rates that could be expected in the Western Region under Improved Land Management Scenarios

Activity	Rate of Carbon Gain (t C ha ⁻¹ yr ⁻¹)	Duration* (yr)
1. Improved agricultural land use		
• Cropland management (reduced tillage, rotational and cover crops, fertility management, erosion control, and irrigation management)	0.1	30
• Grazing land management (herd, woody plants and fire management)	0.1	50
2. Land use change		
• Restoring severely degraded land (cropland, grassland or forest land)	0.25	30
• Grassland (conversion of cropland to grassland)	0.3	50
• Protected lands and 'set asides' (grasslands)	0.5	
• Wetland restoration (conversion of drained land back to wetland)	0.4	100
Total	1.65	

* Note: Duration is defined as the time required for the ecosystem to reach a new equilibrium.

9. Because carbon capture is directly related to plant growth rates, which in turn are influenced by climatic conditions as well as by soil fertility, conservative estimates of carbon capture have been adopted based on a review of Chapter 4 of the IPCC Special Report on *Land use, Land Use Change and Forestry*. These provide broad estimates for activities and ecoregion groupings and will need to be refined as more research into carbon capture in specific regions and land use systems is undertaken. Estimates provided here are a general indication of carbon capture potential under agricultural land management.

17. Land use in the western region is shown in Table 4.3. Opportunities for carbon capture and storage under the CPF are targeted at localities where land degradation is occurring and where there is an opportunity for an increase in carbon capture and storage. This includes farm land, grassland and land classified as being unused (often marginal and degraded desert and steep hills and mountains). Orchards have not been included as they comprise a small area, are not a priority degraded land type and have limited opportunity for increased carbon storage. Similarly, there are limited carbon capture opportunities in built-up areas and in water bodies. Forest data have not been included as potential carbon storage in the forestry sector is calculated separately using more specific information.

Table 4.3: Land Use in The Western Region (in thousands of hectares and percentage of total provincial areas)⁶

Province	Farming	Orchard	Forest	Grass	Water	Unused	Built-up	Total
Chongqing	2556 [31.0%]	163 [2.0%]	3008 [36.5%]	206 [2.5%]	231 [2.8%]	1542 [18.7%]	529 [6.4%]	8235 [100%]
Gansu	4988 [11.0%]	189 [0.4%]	4923 [10.8%]	14370 [31.6%]	167 [0.4%]	19709 [43.3%]	1134 [2.5%]	45480 [100%]
Guangxi	4390 [18.5%]	750 [3.2%]	12500 [52.6%]	1000 [4.2%]	554 [2.3%]	3651 [15.4%]	912 [3.8%]	23757 [100%]
Guizhou	4813 [27.3%]	99 [0.6%]	7887 [44.8%]	1757 [10.0%]	158 [0.9%]	2350 [13.3%]	431 [2.4%]	17495 [100%]
Inner Mongolia	8202 [7.1%]	58 [0.1%]	20016 [17.3%]	68180 [59.0%]	917 [0.8%]	16475 [14.3%]	1661 [1.4%]	115509 [100%]

⁶ Data derived from CPF Appendix on *Extent and Trends in Land Degradation in the Western Region of the PRC*.

Province	Farming	Orchard	Forest	Grass	Water	Unused	Built-up	Total
Ningxia	1294 [24.9%]	72 [1.4%]	443 [8.5%]	2238 [43.1%]	66 [1.3%]	822 [15.8%]	260 [5.0%]	5195 [100%]
Qinghai	682 [0.9%]	9 [<0.1%]	2654 [3.7%]	40482 [56.1%]	1602 [2.2%]	26439 [36.6%]	298 [0.4%]	72166 [100%]
Sha'anxi	4940 [24.0%]	480 [2.3%]	9665 [47.0%]	3243 [15.8%]	248 [1.2%]	1062 [5.2%]	940 [4.6%]	20578 [100%]
Sichuan	6514 [13.5%]	601 [1.2%]	19268 [39.8%]	13753 [28.4%]	814 [1.7%]	5806 [12.0%]	1650 [3.4%]	48406 [100%]
Tibet	366 [0.3%]	2 [<0.1%]	12691 [10.6%]	65094 [54.1%]	5607 [4.7%]	36399 [30.3%]	64 [0.1%]	120223 [100%]
Xinjiang	4199 [2.5%]	187 [0.1%]	6451 [3.9%]	51500 [30.9%]	1180 [0.7%]	101434 [60.0%]	1539 [0.9%]	166490 [100%]
Yunnan	6326 [16.5%]	710 [1.9%]	22450 [58.6%]	1500 [3.9%]	495 [1.3%]	5935 [15.5%]	905 [2.4%]	38321 [100%]
Total for WR	49270 [7.2%]	3320 [0.5%]	121956 [17.9%]	263323 [38.6%]	12039 [1.8%]	221624 [32.5%]	10323 [1.5%]	681855 [100%]
Total for Six dryland provinces	24305 [5.7%]	995 [0.2%]	44152 [10.4%]	180013 [42.3%]	4180 [1.0%]	165941 [39.0%]	5832 [1.4%]	425418 [100.0]

10. The calculation of the carbon capture potential through improved agricultural management in the western region is set out in Table 4.4, based on the following formula:

$$\begin{array}{rclclcl} \text{Potential carbon} & = & \text{Rate of carbon gain} & \times & \text{Applicable area} & \times & \text{Adoption/Conversion} \\ \text{(tonnes / year)} & & \text{(tonnes / ha / year)} & & \text{(ha)} & & \text{Rate} \\ & & & & & & \text{Rate} \\ & & & & & & \text{(}\% \text{)} \end{array}$$

11. The rate of carbon gain is derived from information obtained from international literature in Table 4.2 and the applicable area is based on land use areas set out in Table 4.3. The adoption/conversion rate is the percentage of the area on which improved land management could reasonably be expected to be successfully applied over 10 year and 30-year time frames. In the absence of more specific information, assumptions of adoption/conversion rates have been made using a percentage of each of the three main land use types, farming, grassland and unused land.

12. Based on the foregoing assumptions, improved land management practices on degraded land in the western region has the potential to capture and store an average of 25.7 Mt/C per year by 2012, and 73.2 Mt/C by 2032 (Table 4.4). In 2012, the average annual offset is between the equivalent of 3.6 percent and 4.1 percent of China's national greenhouse gas emissions in 1990 of 2.3 Pg CO_{2-e} (or 643 Mt C). This equates to a carbon storage rate of approximately 0.23 tC/ha/year.

Table 4.4: Adoption/Conversion Rates and Potential Carbon Capture in the Western Region

Land Type / Activity	Rate of Carbon Gain (t C ha ⁻¹ yr ⁻¹)	Area ('000s ha)	Adoption / Conversion Rate (% area)		Potential (Mt C yr ⁻¹)		Area of adoption in 2012 ('000s ha)
			2012	2030	2012	2032	
Restoring severely degraded land	0.25	221,624	10%	30%	5.5	16.6	22,162
Improved farm management	0.1	49,270	20%	50%	1.0	2.5	9,854
Cropland to grassland	0.3	49,270	5%	10%	0.7	1.5	2,463
Grazing land management	0.1	263,323	20%	50%	5.3	13.2	52,664
Grassland set asides (stop grazing)	0.5	263,323	10%	30%	13.2	39.5	26,332
Total:					25.7	73.2	113,477

2. Potential for Carbon Capture through Forest Management

13. PRC has already demonstrated its ability to offset greenhouse gas emissions through afforestation, with a significant increase in new forest cover having been established over the past 30 years. A major proportion of new afforestation has taken place in the north and northwest regions and efforts continue to increase the forest area.

14. To estimate the potential for carbon capture through afforestation and reforestation, relevant data from forest carbon inventories of PRC's forests assessed as part of from the *At Least Cost Greenhouse Gas Abatement Strategy* (ALGAS) for PRC were used.⁷ This strategy includes a modeled projection of carbon capture through afforestation up to 2020 under three scenarios, (i) Baseline Scenario - a 10 percent decrease in the high afforestation rate recorded between 1988 and 1993, (ii) Abatement Scenario I - a further 10 percent increase on the 1988 to 1993 afforestation rate, (iii) Abatement Scenario II - a 30 percent increase on the 1988 to 1993 afforestation rate. The baseline scenario is in accordance with the proposed increase in forest area in PRC in coming decades under the national forest development plan. The plan objective is to increase forest area in PRC from 13.4 percent in 1990 to 17 percent by 2010. Scenario II would result in all land available for forest and agroforestry development in China (26.4 percent) being fully used by 2030.

15. Results of carbon capture potential under Scenario II from the ALGAS report for the NW and western regions are summarized in Table 4.5. Weighting factors have been applied to afforestation to indicate the proportions of available land area that would be used in each of the two regions. Due to the arid/semi-arid climate, it was assumed that only 40 percent of land would be used for afforestation. The annual wood volume increments per hectare are based on national forest inventory data and species used are based on current experience in these regions.

Table 4.5: Carbon Capture for Forestry and Agroforestry in North and NW R regions

Region	Forestry Activity	Rate Of C Gain	Area	Total C Capture
		tC/ha	millions ha	Mt C
North	Assisted natural regeneration	9.5	4.8	45.3
	<i>Pinus tabulaeformis</i>	69.5	3.0	210.1
	Agroforestry	9.3	31.8	296.2
	Poplar	98.6	0.3	33.1
North West	Spruce	55.1	3.2	177.7
	Agroforestry	5.4	11.0	59.3
	Assisted natural regeneration	22.9	6.3	144.2
	Poplar	41.0	1.4	56.7
TOTAL:				1022.6
Percentage Above Baseline				18%
Total Additional C By 2030:				184
Total Additional C By 2012:				61

16. These results tend to indicate that if all ecologically suitable land for forestry in the north and NW regions is reforested over the next 28 years (Scenario 3), the potential carbon capture is estimated to be 1,022 million tC. Scenario II provided an 18 percent increase in carbon

⁷ Xu, D 1999, Forestry and land use change assessment, *ALGAS (Asian Least Cost Greenhouse Gas Abatement Strategy)* – People's Republic of China

capture over the baseline scenario for data presented in the ALGAS study for all of China in 2020. If this percentage is applied, the additional carbon that could be captured in Western PRC in addition to the current baseline would be 184 million tC.

17. Although it is recognised that the foregoing time frame is beyond the scope of the CPF and the scenario described is optimistic, it provides an indication of the carbon capture potential from forestry and agroforestry uses of land. Scaling this figure down to a 10-year time frame provides a more conservative estimate of carbon capture of 61 million tC. This would be equivalent to 9 percent of PRC's 1990 GHG emissions. It is only a broad estimate based on simplified calculations and it needs to be used with caution because:

- (i) There is uncertainty regarding the carbon capture rates and the land areas;
- (ii) It does not take into account other emissions associated with afforestation and reforestation;
- (iii) It cannot be verified that the land areas used comply with the definitions of a Kyoto forest⁸; and
- (iv) The information is based on forest resources survey data, with CO₂ uptake indirectly calculated from past rates of afforestation and deforestation.

All these issues need to be addressed in greater detail as part of a comprehensive forest carbon inventory.

C. PRIORITY AREAS FOR ECOSYSTEM REHABILITATION IN THE WESTERN REGION

18. The benefits of carbon capture should not be considered in isolation of other environmental, social and economic benefits that can be provided through the CPF. Instead, it should be viewed as being one of the tools and mechanisms that can be applied for addressing land degradation while also providing land degradation control, biodiversity conservation and poverty alleviation benefits. Each of the broad carbon capture areas of afforestation/reforestation, agricultural land management and forest protection provides a particular benefit and the CPF will need to include a mix of these activities as appropriate to the local environment. For example, a project in Xinjiang that includes a mix of activities to increase opportunities to support sustainable economic development, to address land degradation and to enhance biodiversity conservation in the Aibi Lake Basin could provide significant carbon capture and storage by:

- (i) Prevention of loss and enhancement of native forest in surrounding mountains and headwaters of the major river systems;
- (ii) Selective planting of shelterbelts around agricultural areas to reduce wind speeds;
- (iii) Conversion of marginal and degraded cropping land to grassland; and
- (iv) Setting aside and protecting remnant indigenous grassland.

19. While large-scale afforestation and reforestation may provide a better opportunity for carbon capture compared to agriculture, its broader environmental, social and economic impacts need to be considered. Trees planted in arid conditions require large amounts of water for establishment, survival and growth. This may not be sustainable in the long term. Many of the land degradation issues of the western region are associated with overuse of increasingly scarce water resources, resulting in the drying of surface water systems and lowering of water tables. OP12 specifically excludes the "conversion of natural landscapes into forest plantations or other monoculture systems", which may preclude the planting of trees in some areas, such as natural grasslands. Furthermore, to satisfy GEF's consistency with the UNFCCC, all

⁸ A "Kyoto forest" is defined as human induced afforestation or reforestation that takes place after 1 January 1990, and includes a change of land use. Clearing natural forest for plantations would not be eligible under the Kyoto Protocol. For example, in China, 4 million hectares were reforested between 1986 and 1993, but it is speculated that much of this reforestation replaced logged natural forest. Any reforestation of this land that was forested immediately prior to reforestation (no land use change) would not be eligible for carbon sink accounting unless there was a change of land use.

afforestation and reforestation must be consistent with UNFCCC definitions. Thus, careful planning is required to ensure that afforestation provides multiple benefits including biodiversity conservation and enhancement, poverty alleviation and that it addresses land degradation, as well as capturing atmospheric carbon.

20. Protection of remnant natural grasslands, grassland rehabilitation and the management of agricultural soils is a priority in much of the western region. Desertification and soil erosion is to a large extent associated with the conversion of grasslands to cropland and overgrazing. While these activities may be less effective in capturing carbon, they provide the greatest opportunity for addressing land degradation problems, while maintaining the regions natural ecosystems, protecting biodiversity, and addressing poverty in pastoral areas.

21. Protecting and enhancing remnant natural forest will minimize the release of carbon to the atmosphere and ensure that this ecosystem becomes a significant carbon sink in the future. The logging and decline of natural forests up until the logging ban in 1998 resulted in net carbon emissions and a loss of biodiversity. Protecting indigenous forests for carbon storage will also provide significant local biodiversity conservation benefits.

22. The priority locations where globally significant atmospheric carbon capture can be achieved through addressing land degradation are through natural forest conservation and grassland rehabilitation in Gansu, Qinghai, Xinjiang, Inner Mongolia, Ningxia and Sha'anxi Provinces/Autonomous regions. All of the demonstration projects proposed in this CPF will have positive carbon capture benefits.