Opportunities for using climate change mitigation and adaptation measures to make progress towards the CBD Aichi Biodiversity Targets: Guangxi Province, China











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IMAGE CREDITS

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Contents

1. Introduction1
1.1 Forests and climate change1
1.2 Forests and biodiversity conservation1
1.3 China's climate change and biodiversity priorities2
2. Guangxi Province
2.1 Biophysical profile and climate3
2.2 Biodiversity5
2.3 Ecosystem services7
3. Mitigation opportunities in Guangxi Province: forests, carbon and biodiversity
3.1 Carbon conservation and protection8
3.2 Increasing carbon13
4. Adaptation opportunities in Guangxi Province: forests, climate change and biodiversity16
4.1 Ecosystem-based Adaptation16
4.2 Adaptation in nature conservation17
5. Conclusions: synergies between climate change mitigation, adaptation and biodiversity conservation in Guangxi Province
6. References21
Annex. Potential Soil Erosion Methods23





1. Introduction

This report examines the opportunities for undertaking forest-based climate change mitigation and adaptation activities in Guangxi Zhuang Autonomous Region in southern China. Particularly, it outlines how these activities could contribute to achieving the Convention on Biological Diversity's (CBD) "Aichi Biodiversity Targets" (Box 1) and thus focuses on synergies between climate change mitigation, adaptation and biodiversity conservation. It aims to provide insights for decision makers and technical advisers, including those within the Environmental Protection, Agriculture, Forestry, and Water Resources departments. Such insights will support them on how spatial analyses can contribute to identifying areas where such synergies can be achieved, and how such analyses could inform planning and policy making processes.

1.1 Forests and climate change

Deforestation can play an important role in carbon emissions. The contribution of deforestation and forest degradation to global CO_2 emissions is generally considered to represent 6–17%

Box 1. Convention on Biological Diversity (CBD) "Aichi Biodiversity Targets"

In October 2010, the Parties to the Convention on Biological Diversity (CBD) adopted a time-bound framework for action on biodiversity in the form of the Strategic Plan for Biodiversity for the period 2011–2020. The strategic plan was accompanied by 20 specific targets: the Aichi Biodiversity Targets. These targets include objectives that range from conservation of marine and terrestrial ecosystems, to access to genetic resources and benefits arising from their use, including targets relevant to climate change adaptation and mitigation policies, see Box 3. The targets are global, but actions to achieve them are primarily implemented at the national, sub-national and local level. The Strategic Plan is translated into national circumstances and implemented by countries through National Biodiversity Strategies and Action Plans (NBSAPs).

of total emissions (van der Werf et al. 2009). Forest-based mitigation activities, including reducing deforestation and forest degradation, afforestation, reforestation, forest restoration and conservation, have therefore received attention in climate change policy.

Forest management can also be important for climate change adaptation, because forests provide key ecosystem services, such as soil stabilisation, regulation of water flows, provision of timber and of non-timber forest products. Using biodiversity and ecosystem services to help people adapt to climate change is termed "ecosystem-based approaches to adaptation" (see **Box 2**).

Climate change will affect species and ecosystems as well as people. For example, as the climate changes the suitability of different locations for particular ecosystems and species will change, putting pressure on species and ecosystems especially at the margins of their distributions. This is likely to cause shifts in the distribution of some ecosystems and species. Actions can be undertaken to help nature conservation adapt to such climate change impacts, termed "adaptation in nature conservation". Examples include establishing protected areas and natural corridors, management of forest margins to maintain microclimate, or undertaking reforestation with climate resilient species.

1.2 Forests and biodiversity conservation

The most species rich areas of the world are within forest ecosystems (Myers et al. 2000). Protecting, restoring and increasing natural and semi-natural forest are therefore important activities in the fight against biodiversity loss. At the same time, the need for addressing biodiversity loss in order to protect human well being has been recognised within the CBD's strategic plan for 2011–2020, which sets out the Aichi Biodiversity Targets to be achieved by 2020 (henceforth called Aichi Targets). Given the

Box 2. Definitions (adapted from Doswald and Osti 2011)

Ecosystem-based approaches to mitigation – the use of ecosystems for their carbon storage and sequestration services to aid climate change mitigation. Emissions reductions are achieved through avoided deforestation, and creation, restoration and management of ecosystems (e.g. forest restoration, afforestation, protection).

Ecosystem-based approaches to adaptation – the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (CBD 2009); this may include sustainable management, conservation and restoration of ecosystems, as part of an overall adaptation strategy that takes into account the multiple social, economic and cultural benefits for local communities (CBD 2010). Adaptation is facilitated through both specific ecosystem management measures (e.g. watershed management) and through increasing ecosystem resilience to climate change (e.g. forest restoration, choice of species in afforestation).

Adaptation in nature conservation – conservation action that increases the resilience of species and ecosystems to climate change and facilitates their adaptation (e.g. facilitating movement of species across the landscape to enable shifts in distributions, reducing other sources of harm known to interact with climate effects).





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link between forests and biodiversity, undertaking forest-based mitigation and adaptation activities has the potential to contribute towards achieving the Aichi Targets. Equally, actions to achieve the Aichi Targets have the potential to support climate change mitigation and adaptation (Miles et al. 2012).

There are five Aichi Targets that are particularly relevant to forest-based mitigation and adaptation activities (see **Box 3**).

1.3 China's climate change and biodiversity priorities

China is a non-Annex I Party signatory to the United Nations Framework Convention on Climate Change (UNFCCC). Its National Climate Change Programme outlines key policies and measures to address climate change. Furthermore, China has outlined specific forest-relevant actions to undertake in its current five-year climate change plan (2011–2015) (National Development and Reform Commission (NDRC) 2007).

- Mitigation: increase afforestation and carbon sequestration; improve management of resources.
- Adaptation: undertake adaptation measures in key sectors, such as agriculture, forestry, water and in certain areas (fragile ecosystems); improve capacity to guard and alleviate natural disasters (due to extreme weather and climate); improve management of resources.

China is also a Party to the CBD, and has identified strategic goals, tasks, priority areas and actions for biodiversity conservation in its NBSAP: the China National Biodiversity Conservation Strategy and Action Plan (2011–2030). This Plan identifies the mountain area of south-west Guangxi as a priority area for biodiversity conservation. Conservation priorities for the area include improving the conservation of ecosystems such as tropical rainforests and monsoon forests, and improving the conservation of key wildlife such as endemic primates, the oriental small-clawed otter, and rare tropical plants. Actions identified under the plan include strengthening the establishment of nature reserves in the areas of priority for biodiversity conservation, optimizing their spatial structure and improving the connectivity between them.

Box 3. Aichi Targets relevant to forest-based climate change mitigation and adaptation

Target 5: By 2020, the rate of loss of all natural habitats, including forests, is at least halved and where feasible brought close to zero, and degradation and fragmentation is significantly reduced.

Target 7: By 2020, areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity.

Target 11: By 2020, at least 17 per cent of terrestrial and inland water, and 10 per cent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, are conserved through effectively and equitably managed, ecologically representative and well connected systems of protected areas and other effective area-based conservation measures, and integrated into the wider landscapes and seascapes.

Target 14: By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable.

Target 15: By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.

In relation to forests in particular, China's 4th National Report to the CBD identifies the following priorities:

- 1. Strengthening the establishment and management of nature reserves;
- 2. Implementing six key forestry projects;
- 3. Strictly controlling pollution and ecological destruction;
- 4. Promoting the conservation and sustainable use of biological resources;
- Preventing and controlling invasive alien species; and;
- 6. Formulating national strategies and key measures to cope with and reduce adverse impacts of climate change on biodiversity (Ministry of Environmental Protection 2008).

The report provides a first investigation into the opportunities for achieving climate change mitigation, adaptation and biodiversity conservation in Guangxi Zhuang Autonomous Region (henceforth called Guangxi Province) and discusses possibilities for synergies between such activities.

2. Guangxi Province

2.1 Biophysical profile and climate

Guangxi Province is located in subtropical south China, bordering with Vietnam. It is a mountainous region with abundant water resources and is notable for its Karst landscapes, which have originated through the dissolution of underlying limestone (**Map 1**). In the past, intensive land use in the region has led to soil loss and land degradation and associated loss of productivity. Since the 1990s, some efforts have been made to restore the area, e.g. through the "Grain to Green" project (Chen et al. 2012).

According to data from the Environmental and Ecological Science Data Centre for West China, vegetation cover in Guangxi is mainly forest (29%), cultivated vegetation (26%) and scrub (26%) (Map 2). According to a report from the World Bank and Guangxi Forestry Bureau, however, the land use category of "forestry land" (comprising forest stands, sparsely-stocked forest stands, shrub land, land recently afforested, land occupied by nurseries and un-stocked forest lands) covers 57% of the Province (Cossatler and Barr 2005). Guangxi's forestry land is divided into two categories: "commercial forests" (defined as forest stands, either natural or planted, located on forestry land under commercial management) and "forests for environmental services" (defined as forest stands,



Karst Landscape near Yangshuo by Jesse Varner (CC BY-NC-SA 2.0). Accessed 2 July 2014. https://flic.kr/p/3D2Ru



Map 1. Karst landscape within Guangxi Province



Method and data sources: Elevation: GTOPO30 (Global 30 Arc-Second Elevation Data Set) (1996) Available online at http://edcdaac.usgs.gov/gtopo30/gtopo30/gtopo30.html from the EROS Data Center (EDC) Distributed Active Archive Center (DAAC), Sloux Falls, South Dakota, USA. Also see: Gesch, D.B., Verdin, K.L., and Greenlee, S.K. 1999. New land surface digital elevation model covers the earth. Eos, Transactions, American Geophysical Union, 80(6):69-70.

Karst Landscape: Working Programme of Environmental Effect Assessment for Medium and Long-term Development Plan of the Petrochemical Industry around the Coast of Guangxi Province, July 2007, drafted by College of Environmental Science and Engineering, Tongji University and Guangxi Research Academy of Environmental Sciences, unpublished Provincial boundary and waterbodies; National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China.

either natural or planted, located on forestry land for environmental services); the former being of notably greater extent than the latter (Cossatler and Barr 2005).

The climate of Guangxi Province is characterised by short winters and long summers, with annual average temperatures between 16 and 23°C. The monsoon season occurs between April and September. Current climate challenges faced by the area include unpredictable extreme weather (as in

many parts of China, see Piao et al. 2010) resulting in periodic drought, floods, hailstorms, cold snaps and typhoons, which have hit different parts of the Province. An analysis of spatial and temporal changes in extreme temperature and extreme precipitation showed that the magnitude of these extremes have on average increased over all regions in Guangxi Province between 1960 and 2009, though changes vary spatially and according to season (Nie et al. 2012). The conjunction between precipitation and temperature extremes has increased the

Map 2. Distribution of major vegetation classes in Guanxi Province The land cover in Map 2 was derived from 1:4,000,000 China Vegetation, made in 1979.



Method and data sources:

Land cover: Environmental and Ecological Science Data Center for West China, National Natural Science Foundation of China. Available at: http://westdc.westgis.ac.on Provincial boundary: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China.

Karst Landscape: Working Programme of Environmental Effect Assessment for Medium and Long-term Development Plan of the Petrochemical Industry around the Coast of Guangxi Province, July 2007, drafted by College of Environmental Science and Engineering, Tongli University and Guangxi Research Academy of Environmental Sciences, unpublished, Provincial boundary and waterbodies: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China.

incidence of droughts and floods, impacting agricultural land, drinking water, people's homes and lives (Nie et al. 2012; Zhou et al. 2012).

Climate change projections for the end of the 21st century indicate potential increases in temperature and slight increases (or decreases) in precipitation over southern China, with potentially more precipitation in the summer than winter, suggesting increased incidences of drought and floods (Xu et al. 2006; Piao et al. 2010).

2.2 Biodiversity

Guangxi Province is rich in biodiversity including many endemic plants (Map 3), particularly in the mountainous regions, distant from the main areas of agricultural activity (Map 2). Besides being unique ecosystems where high levels of species richness and endemism occur, the mountain areas act as a microclimate refuge and offer protection from human impact (Hou et al. 2010). The southern lowlands of Guangxi Province are part of the Indo-



Map 3. Distribution of biodiversity in Guangxi Province: a) number of plant and vertebrate species per county; the districts shown in dark blue have a high richness of both plant and animal species, while those in darker green have high plant species richness but lower relative richness in animal species, and the counties in darker shades of brown have high richness of animal species and lower relative richness in plant species; b) endemic plant species richness by county.





Burma biodiversity hotspot, an area of exceptionally high endemism identified as being of great global conservation importance (Myers et al. 2000).

In Guangxi Province, biodiversity loss has occurred mainly due to land use change (towards agriculture and forest plantations) often resulting in subsequent land degradation, e.g. in the Karst areas (Wen et al. 2011). Guangxi Province contains 78 protected areas covering approximately 6% of the land area. Four levels of protected areas exist: City; County; Provincial; and National (see section 3).

2.3 Ecosystem services

Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment (MA) 2005). These include: provisioning services, such as supply of food, water and raw materials; regulating services, such as buffering of natural hazards, soil erosion prevention and climate regulation (through green house gases (GHG) sequestration and storage); and cultural services, which include not only recreation and tourismrelated activities but also the aesthetic and spiritual value of natural places.

Provision of food, timber and other forest products, are important services provided by ecosystems.

The population of Guangxi Province is largely dependent on agriculture (farming, fishing and animal husbandry) and forestry, with farming and animal husbandry providing the highest revenues. Farming is concentrated in a band from southwest to northeast of the province, while fishing and forestry are more restricted to a few hotspots on the coast and in the mountains, respectively (**Map 4**).

The vegetation of Guangxi Province, including forest, provides many regulatory ecosystem services, including carbon sequestration and storage, which are important in climate change mitigation, and water regulation and erosion control, which are important in climate change adaptation.

Guangxi Province is also rich in water resources, with approximately 937 rivers providing not only drinking water and irrigation but also hydroelectric power. Despite the large water capacity, there is an imbalance between supply and demand, inadequate water management during floods and drought, and pollution (Department of Agriculture of Guangxi Zhuang Autonomous Region 2011).

Guangxi Province ecosystems also provide an important cultural service in supporting tourism, especially in the Karst landscapes (**Map 1**).



Bird's-eye view, Xingping, North Guangxi © Dimitry B (CC BY 2.0). Accessed 24 June 2014. https://flic.kr/p/mjjSCp



Map 4. Net annual income (2008) of rural households in Guangxi Province from each of the four main primary industries: farming, forestry, fishing and animal husbandry



Primary Industry: Guangel Statistical Yearbook 2009. County boundaries: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China. Provincial boundary: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China.

3. Mitigation opportunities in Guangxi Province: forests, carbon and biodiversity

The role that forestry plays in China's climate change mitigation plans is mainly increasing carbon stocks through afforestation and reforestation. In this section, we first examine current carbon stocks and their spatial relationship with biodiversity and then look at the potential for increasing these stocks.

3.1 Carbon conservation and protection

Although biomass carbon conservation is not a major focus of China's climate change mitigation strategy, the protection of forests does form part of its biodiversity strategy. Protecting forests for biodiversity will also protect the carbon stored within them, potentially reducing CO₂ emissions

from deforestation and forest degradation, and thus supporting climate change mitigation. Preventing emissions from forests which contain the highest carbon stores can have the largest impact in reducing emissions. Using global scale data, the maps presented in this section give an overview of the spatial relationship between carbon stocks and biodiversity. Although maps of this kind give a broad indicative picture, more accurate regional or national data would be needed for detailed land use planning.

Carbon stocks include both the carbon stored within living organisms (biomass carbon) and that stored within soils. Biomass carbon is mainly formed of woody materials present both above ground and below ground (i.e. roots). To produce these indicative maps, a pan-tropical map of biomass carbon produced by Saatchi et al. (2011) was used to estimate the above and below-ground biomass carbon contained within Guangxi Province, (see Saatchi et al. (2011) for further information on the pan-tropical map). According to this dataset, approximately 1.2–2.6 Gigatonnes (Gt) of carbon are stored in above and below-ground biomass in Guangxi Province (**Map 5a**). These data provide a more detailed view of the variation in carbon stocks than is provided by other sources (e.g. a nationally produced map for the province is based on only two broad vegetation types, with each assigned a single average carbon value making it difficult to distinguish between areas of high and low carbon).

Soil organic carbon can make up a significant proportion of total carbon in terrestrial ecosystems, and therefore can have a potentially large impact on emissions from land use change and so climate change. An indication of the distribution of soil organic carbon can also be derived from global data (**Map 5b**). According to the global data, approximately 2 Gt of carbon is stored in the soils of Guangxi Province. This total aligns more closely with the views of national experts than estimates from other sources (e.g. the values within a national level dataset of soil carbon were deemed too high when reviewed by national experts).

As estimates of soil carbon stock are currently less certain than for biomass carbon, and it is more difficult to predict the impacts of land use change on soil carbon than on biomass carbon (Scharlemann et al. 2014), all subsequent analyses in this report are based on biomass carbon only. However, soil carbon can be a significant proportion of total carbon in places and so better data would allow decisions to take account more fully of the impact of certain actions on carbon stocks and emissions.

Guangxi Province forests can be divided into needleleaf forests, mainly Masson pine and Chinese fir, and broadleaf forests, which are largely Eucalyptus plantations (**Map 6**). Overlaying the carbon maps (above) with the distribution of needleleaf and broadleaf forest areas of the Province, shows that much of the forest area coincides with the areas of high carbon (see **Table 1**). Depending on the pressures they are under, preventing deforestation in areas of high carbon may have significant impact on reducing emissions and in climate change mitigation.

Table 1. Gigatonnes of biomass carbon (GtC) in needleleaf

 and broadleaf forest within Guangxi Province

Carbon class	GtC	%
Low	0.05	7
Medium Low	0.07	10
Medium	0.10	13
Medium High	0.12	17
High	0.19	26
Very High	0.20	27

Forest areas are generally formed of young or middleaged stands. The age of the forest will affect its carbon content, since higher biomass, and therefore higher carbon content, is typically found in older stands (Pan et al. 2004). "Forests for environmental services" are generally comprised of a higher percentage of younger and middle-age stands than commercial forests (for definitions of these forest categories, see page 4) (Cossalter and Barr 2005). However, young forests for environmental services, which are in the process of restoring are likely to be net sequesters of carbon as their biomass is developing, and can therefore still have an important role in reducing the net total emissions.

In assessing the spatial distribution of carbon it is also important to consider the spatial distribution of potential pressures and competing demands for the land. Areas that have high potential pressures may be at most risk from deforestation and forest degradation and indicate the greatest need for protection. Conserving areas that would otherwise be deforested or degraded can reduce carbon dioxide emissions and support climate change mitigation. On the other hand, forest restoration actions may be most successful in areas where there is little human pressure. The relationship between primary industry (i.e. farming, forestry and animal husbandry) and forests is presented in Map 7; the areas where income from primary industry is greatest may be associated with greater economic pressure for land use conversions. Karst areas are notably free from both forests and primary industry due to the landscape structure, as well as due to land degradation and people's migration out of the area (Wen 2011; Chen 2012). Mountainous areas to the west of the region have both less forest and less primary industry than mountains in the east, which are covered by forests. The forests in the eastern mountains are mainly used for forestry, see Map 4. People that live close to forests may be particularly dependent on the ecosystems services they provide, though low primary industry areas are also associated with lower population density. The population density in relation to biomass carbon in the Guangxi Province is presented in Map 8.

Protected areas, designated for their biodiversity and ecosystem services, can protect the carbon stored within them. Areas currently protected in Guangxi Province contain approximately 0.16 Gt of biomass carbon (**Map 9**). This equates to approximately 8% of the total biomass carbon of the Province (1.90 Gt), illustrating the important role that such areas can play in reducing emissions from deforestation and in the mitigation of climate change, in addition to helping to achieve Aichi Target 11.

In addition to the current protected areas, the





Map 6. Biomass carbon according to forest type



Method and data sources: Biomass carbon: Saatchi, Sassan S., et al. (2011) "Benchmark map of forest carbon stocks in tropical regions across three continents." Proceedings of the National Academy of Sciences 108.24: 9899-904.

Forest:Environmental and Ecological Science Data Center for West China, National Natural Science Foundation of China. Available at. http://westdc.westgis.ac.cn.

Provincial boundary and water bodies: National Fundamental Geographic Information System, 1: 4.000.000 database. National Geomatics Center of China.

Nature Conservancy (TNC) in China has indentified 32 terrestrial Priority Conservation Areas (PCA), some of which are included within Guangxi Province (orange areas in **Map 9b**), and which the Chinese government has aligned with its conservation priorities (TNC 2014). PCAs in Guangxi Province cover 78 000 km² of the Province and contain a relatively large proportion of the total biomass carbon (approximately 0.75 Gt, or 39% of the total in Guangxi Province) (Table 2). These areas also fall within the areas of highest species richness within the region (Map 3).

The overlap between biomass carbon and county species richness, which covers vascular plants, terrestrial animal and fish (see Map 3a), is presented in Map 10.

As Maps 8 and 9 exemplify, different datasets can be used to explore the overlap between areas of high biodiversity and carbon stock. Considering such data and analyses provides potential basis for identifying actions that would simultaneously protect both biodiversity and carbon stocks, such that climate





Map 7. Income from primary industry (farming, forestry, animal husbandry) and forests with elevation contours in Guangxi Province

Method and data sources: Primary Industry; Guangxi Statistical Yearbook 2009. Forest: Environmental and Ecological Science Data Center for West China, National Natural Science Foundation of China, Available at: http://westdc.westgis.ac.cn, County boundaries: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China. Provincial boundary: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China.

change mitigation activities could help achieve the Aichi Targets, including Targets 5 (reducing habitat loss) and 11 (conserving through protected areas), and vice versa. However, it should also be noted that several key biodiversity priority areas are currently low in carbon, and so there is a risk of displacing pressures onto these areas if only areas which are high in carbon are conserved.

Table 2. Gigatonnes of biomass carbon (GtC) and percentage (%) in each class within the Priority Conservation Areas

Carbon class	GtC	%
Low	0.05	7
Medium Low	0.11	15
Medium	0.13	17
Medium High	0.14	19
High	0.16	21
Very High	0.16	21







Method and data sources:

Biomass Carbon: Saatchi, Sassan S., et al. (2011) "Benchmark map of forest carbon stocks in tropical regions across three continents." Proceedings of the National Academy of Sciences 108.24: 9899-904. County boundaries: National Fundamental Geographic Information System, 1: 4.000,000 database. National Geomatics Center of China

cial boundary and water bodies: al Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China Population data: Guangxi Statistical Yearbook 2009

3.2 Increasing carbon

Afforestation (along with reforestation and forest restoration) is a priority for China. In Guangxi Province, parts of the Karst landscape, for example, were heavily deforested and converted to cultivated land or pasture. These areas are at risk of degradation or are currently degraded as the soil loses its productivity (Yangugang et al. 2011; Chen et al. 2012). Afforestation and reforestation may be suitable in areas that are not currently forested, other natural ecosystems and/or in use for settlements. China's "Grain for Green"

programme (Food and Agricultural Organisation of the United Nations (FAO) 2004) has been implemented in Guangxi Province (Chen et al. 2012) and specifically targeted such degraded areas. Guangxi Province also holds the first afforestation Clean Development Mechanism (CDM) project (2008–2068), which aims to plant approximately 4000 ha of mixed species and a small proportion of eucalyptus on degraded land for environmental and development objectives (Gong et al. 2010).









Method and data sources: Biomass Carbon

Saatchi, Sassan S., et al. (2011). "Benchmark map of forest carbon stocks in tropical regions across three continents." Proceedings of the National Academy of Sciences 108,24 (2011): 9899-904

Provincial boundary and water bodies

National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China. Species Richness: Guangxi Biodiversity Assessment and Research Report (2008) provided by the Environmental Protection Bureau, Guangxi Province. Unpublished

Guangxi Province's "Green Bagui" project was launched in 2010 aiming to plant trees in mountainous areas, and plant patches of greenery in towns and villages, as well as along transportation passages. The name "Bagui" refers to the Province. In 2011, an area of around 2767 km² was afforested. For the first time, the forest coverage of the Province exceeded 60% (60.5%). Native species planted during the project so far include Osmanthus fragrans, Salix babylonica, Metasequoia glyptostroboides, Liquidambar acalycina, Lagerstroemia indica, Verbenaceae Tectona grandis, Bombax ceiba, Dalbergia odorifera, and Cinnamomum camphora. It has now been announced that the mission of the project for the year 2013 has been accomplished. By the end of May 2013, an area of ~ 2400 km² was afforested and more than 23 million people took part in the planting of over 90 million trees (Guangxi Forestry Department 2013).

Whether and to what extent biodiversity and ecosystem services will benefit from afforestation, reforestation and forest restoration, depends on where and how these activities are implemented. For example, the type of tree planted is an

important factor. Eucalyptus plantations have been favoured in the past in Guangxi Province and other south eastern regions, as they are fast growing and produce good quality timber (Bai and Gan 1996). Biodiversity and ecological conditions in eucalyptus plantations depend on where these are planted and how they are managed. Established on barren land or when in inter-cropping usage, they can increase species richness and improve soil conditions (FAO 1996). However, a 45-year forest restoration study conducted in the neighbouring province of Guangdong showed that compared to a control plot of barren land, eucalyptus plantation forest had higher surface runoff than the barren land though it had 20% less soil erosion, whilst mixed forest had eliminated both (Ren et al. 2007). Furthermore, eucalyptus forest had less species richness than mixed forest. Careful consideration of the potential negative impacts on biodiversity and ecosystem services needs to be undertaken when thinking of afforesting areas of high non-forest biodiversity or endemism.

Maps of areas of deforested land and degraded forest are important for identifying areas that might be in need of restoration. Areas that are currently low in carbon may cover areas that are in need of restoration, although they are likely to also cover important non-forest areas which are naturally low in carbon. Depending on their current land use and availability, such areas may be suitable for afforestation, reforestation or restoration, or could be enhanced through introduction of sustainable management strategies. The potential for such activities also depends on current land use. In some places, afforestation or reforestation activities could create corridors between areas important for biodiversity and protected areas, potentially benefiting biodiversity and ecosystem services depending on how they are implemented. Such corridors could also support the migration of species, essential for enabling adaptation of species to climate change (see next section). Reducing forest fragmentation, increasing connectivity between protected areas and restoring degraded forest ecosystems are direct contributions to several of the Aichi Biodiversity Targets (i.e. 7, 11, 14 and 15), while also serving climate change mitigation and adaptation.

The above maps of biodiversity priority areas and carbon can help identify areas that are rich in biodiversity but poor(er) in carbon, potentially indicating deforested or degraded forest areas or areas of secondary succession. However, definitive identification of degraded land and its current use would be need to inform any afforestation or reforestation strategy.

4. Adaptation opportunities in Guangxi Province: forests, climate change and biodiversity

4.1 Ecosystem-based Adaptation

Forests, their state and resilience, are an important component in determining the sensitivity of people to climate change and can be important in adaptation to climate change. They can protect against soil erosion and water resource losses, as well as provide protection from storms (i.e. shelter belt), resources for livelihoods (e.g. forestry, tourism, non-timber forest products, etc.) and essential supporting services for these livelihoods (e.g. pollination, watershed protection, etc.). Many of the forest-based activities that could be conducted as part of ecosystem-based adaptation to climate change overlap largely with those that have been discussed in the section on climate change mitigation, i.e. conservation of forests and reforestation, forest restoration and afforestation. However, identifying areas where such activities



Francois langur (Presbytis francoisi) © Magnus Manske (CC BY 3.0). Accessed 24 June 2014. http://en.wikipedia.org/wiki/ File:Francois_langur_head.jpg

would yield the greatest adaptation benefit requires additional data and analyses. A vulnerability assessment would be needed in Guangxi Province to identify areas (e.g. villages/people/sectors/ ecosystems) that are particularly vulnerable to climate change. Nevertheless, the following analyses may help point to some guiding questions for such an assessment. Additionally, it can help to identify potential additional benefits from mitigation actions such as forest conservation and enhancement of forest carbon stocks, and where synergies between mitigation and adaptation actions may be achievable.

The delineation of watersheds can support watershed management, and so adaptation to climate change, including increased climatic variability, which may impact water management. Ensuring that good watershed management is undertaken in areas at risk from climate change impacts, focusing on ecological restoration and using an ecosystem approach taking climate change into account, will be necessary to ensure long term resilience of the socio-ecological system.

The majority of Guangxi Province is represented as a single, large basin. A number of major rivers flow through the Province, including the Rivers Xi and Li, likely contributing to the delineation of such a large basin. Map 11 shows that watershed management needs to take into account large areas with diverse topography and land use needs (e.g. farming, forestry, etc.). In the past, China has implemented large-scale land reforms to decrease soil erosion and conserve water mainly through reclaiming farmland and afforestation (Dudgeon 1995; FAO 2004; Hageback et al. 2005; Chen et al. 2012). Meeting the needs of farmers and a future growing population, however, may require careful planning in terms of land use, especially in a changing climate. Taking an ecosystem-based approach to adaptation, where reduction of people's vulnerability is sought through using ecosystems and biodiversity, should enable multiple social, economic and environmental benefits in Guangxi Province.

One potentially important issue within watersheds management is the potential for climate change to increase high precipitation events, potentially leading to water erosion on non-vegetated slopes. **Map 12** shows actual and potential soil erosion maps for Guangxi Province. The current soil erosion map models the likely current erosion given current vegetation cover, rainfall, slope and land use; the potential soil erosion map illustrates how soil erosion may increase if vegetation cover was removed (see Annex I for methods). Forests planted in areas of high erosion could not only decrease erosion but also increase infiltration of water and potentially provide some protection against flooding and drought, depending on how it is undertaken and the local context. The "Grain for Green" Programme in China, implemented between 1999–2002, specifically targeted areas of poor farmland on slopes, to reconvert them to either grassland or forests (commercial or for environmental services) and reduce soil erosion and improve the stability of water resources (FAO 2004). Forests are also useful as protection forests, i.e. shelter belts, and many plantations, especially eucalyptus, have been planted for this purpose, as well as for soil and water conservation (FAO 1996). The first eucalyptus plantation in the Province was established in 1935 and further plantations followed for socio-economic purposes, for example for timber, fuel wood and extraction of essential oils (FAO 1996). However, eucalyptus forest is less beneficial in terms of biodiversity and ecosystem services than mixed forest (Ren et al. 2007).

4.2 Adaptation in nature conservation

Forests can support human adaptation to climate change, as described in section 4.1. However, forests in tropical and subtropical areas, especially in mountainous areas, are also highly vulnerable to climate change themselves (FAO 2010; Kant and Wu 2012). Supporting forests to adapt to climate change can help maintain the ecosystems services they provide, as well as directly benefiting the species they contain. Helping species adapt and reducing the negative impact of climate change is a priority for China and the CBD. Restoration activities, especially if carried out with native climate change resilient species, can support nature conservation as well as human adaptation. In particular, creating corridors can enable species to track changes in climatic conditions.

Increasing the general protection of biodiversity in forests and protected area coverage can also support climate change adaptation in nature conservation, as species and ecosystems that are not under multiple different pressures are likely to show higher resilience. Undertaking restoration and conservation activities in biodiversity priority areas can increase the benefits to species conservation. Areas of priority for biodiversity conservation have already been identified (see PCA areas, **Map 9b**) and TNC is working in these areas on restoration activities to strengthen key ecosystem services and attenuate the impacts of climate change.



Map 11. Watersheds in Guangxi Province, created using a 3-arc second (~90m) resolution void-filled Digital Elevation Model (DEM) from HydroSHEDS (Lehner et al. 2008). Flow direction and flow accumulation for Guangxi Province were calculated using the DEM. A stream order network layer was created as part of this analysis in order to validate the representation of the flow network.



Method and data sources: Elevation: Lehner, B., Verdin, K., Jarvis, A. (2008): New global hydrography derived from spaceborne elevation data. Eos. Transactions, AGU, 89(10): 93-94. Sec. http://hydrosheds.cr.usgs.gov/

Provincial boundary and water bodies: National Fundamental Geographic Information System, 1: 4,000,000 database. National Geomatics Center of China.



Boatman at Work © Peter (CC BY-NC-SA 2.0) Accessed 2 July 2014. https://flic.kr/p/nBsHUz

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5. Conclusions: synergies between climate change mitigation, adaptation and biodiversity conservation in Guangxi Province

Under climate change, Guangxi Province is likely to experience an overall decrease in precipitation; however, spatial and temporal variability are high, with certain areas and/or time periods experiencing increases in precipitation. There are also likely to be overall increases in temperature and frequency of extreme events. This will affect not only people, but also species and ecosystems. Mitigation and adaptations activities can thus offer potentially large benefits.

Ecosystem-based approaches, especially forestbased, can produce win-win options for both climate change mitigation and adaptation. Furthermore, given their link with biodiversity, such activities can provide opportunities to make progress towards achieving the CBD Aichi Targets that are directly relevant for forest-based climate change mitigation and adaptation, in particular targets for reducing deforestation (Target 5), restoration (Target 15), protected areas (Target 11) and restoring and safeguarding ecosystem services (Target 14). Focusing restoration and conservation activities in areas that are important for biodiversity, such as Priority Conservation Areas (PCAs), and areas important to people for ecosystem services (such as soil erosion control), can enhance the multiple benefits that are achieved. Spatial analyses, such as the ones set out in this report, can help maximise these synergies between climate change mitigation, adaptation and biodiversity conservation. For example, they can highlight the location of forest areas and areas of high carbon stocks, as well as their coincidence with areas that may be important for biodiversity, watershed management, soil erosion and population density.

Afforestation, as long as species choice and area are considered (in terms of climate suitability and environmental impact), could also yield mitigation, adaptation and biodiversity benefits in areas that have been previously deforested or in areas that are important for people. Ensuring connectivity across the landscape will help species' adaptation to climate change and protect biodiversity. The maps show where forests are currently not present and could potentially be enhanced; although more detailed data on areas which have been deforested, areas in need of restoration and current land use are needed. Moreover, it is appropriate to consider tree species chosen when undertaking afforestation (or reforestation) for not only their suitability for the local climate, but also their impact on the environment.

The report aims to provide decision makers and technical advisers with insights into a broad range of spatial analyses that can help to identify areas where synergies can be achieved for climate change mitigation, adaptation and biodiversity conservation. Province-wide spatial analysis can inform planning and policy making. Detailed planning of activities then requires a finer understanding of the land use and past land use history, as well as further data, for example, about the location of forest plantations and current state and pressures, including deforestation and degradation areas. Further analyses including climate change vulnerability assessment for adaptation purposes would also be useful. While the data used at the time of publication was the best available data, revision by experts at provincial level would be valuable to ensure the data reflects the actual situation. The present study for Guangxi Province could serve as a starting point for the design of more detailed analyses and the development of similar work in other provinces of China.



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Annex. Potential Soil Erosion Methods

The calculation of the potential soil erosion followed the Revised Universal Soil Loss Equation (RUSLE) in Renard, K.G., Foser, G.R., Weesies, G.A., et al. (1997) Predicting soil erosion by water: A guide to conservation planning with the revised universal soil loss equation (RUSLE) [M]. Agriculture Handbook No. 703. U.S. Department of Agriculture. Washington, DC.

Soil retention can be expressed mathematically as:

ΔA = Ep - E

 $Ep = R^*K^*LS$

 $E = R^*K^*LS^*P^*C$

Where

 ΔA is the amount of soil conservation

Ep= potential soil erosion (potential soil erosion without vegetation cover)

E = mean annual soil loss (t ha-1 year-1) (the soil erosion under current land cover and management condition)

R = rainfall erosivity factor (MJ mm ha-1 h-1 year-1 K = soil erodability factor (t ha h ha-1MJ-1 mm-1 LS = slope length and slope steepness factor P = supporting practices factor C = cover management factor

R factor

The R factor is a measure of the erosion force of rainfall based on annual precipitation (p) and peak intensity of rainfall over the year (monthly precipitation, pi) (Wischmeier, W.H. & Smith, D.D., (1978) Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agriculture Handbook No. 537. USDA/Science and Education Administration, US. Govt. Printing Office, Washington, DC. 58pp.):

$$\mathsf{R} = \sum_{i=1}^{12} 1.735 \ge 10^{\left(1.5 \log\left(\frac{pi^2}{p}\right) - 0.8188\right)}$$

Where Log = In In(x) = Log10x $In (pi^2/p) = Log10 (pi^2/p)$

Rainfall data was downloaded from China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/home.do)

This equation was calculated using ArcMaps raster calculator.



K factor

The K factor is the soil erodability factor – the susceptibility of the soil to erosion and the rate of runoff. It is calculated using the Erosion-Productivity Impact Calculator (EPIC) model (Williams J.R. (1990) Quantitative Theory is Soil Productivity and Environmental Pollution. Philosophical Transactions: Biological Sciences. 329 (1244), 421-4280:

$$\mathbf{K} = \left\{ 0.2 + 0.3 \exp\left[-0.0258 \times \text{SAN} \times \left(1 - \frac{\text{SIL}}{100} \right) \right] \right\} \times \left(\frac{\text{SIL}}{\text{CLA} + \text{SIL}} \right)^0 \cdot 3 \times \left[1.0 - \frac{0.25 \times \text{C}}{\text{C} + \exp(3.72 - 2.95 \times \text{C})} \right] \times \left[1.0 - \frac{0.7 \times \text{SN}_1}{\text{SN}_1 + \exp(-5.51 + 22.9 \times \text{SN}_1)} \right]$$

Where SAN = % sand (0.1–2mm) SN1 = 1 – SAN/100 SIL = % silt (0.002–0.1mm) CLA = % clay (<0.002mm) C = % organic carbon = % organic matter * 0.58 Soil data (topsoil 0–30cm) downloaded from http://www.resdc.cn/

In ArcMap individual rasters were created from the Harmonized World Soil Database (HWSD) for the variables of the above equation (SAN, SN1, SIL, CLA and C). The equation to derive K was then calculated using the raster calculator in ArcMap.

LS factor

The LS factor considers the contribution of slope length and slope steepness to erosion. It was calculated using a C++ executable (Van Remortel, R.D., Maichle, R.W., & Hickey, R.J. (2004). Computing the LS factor for the Revised Universal Soil Loss Equation through array-based slope processing of digital elevation data using a C++ executable. Computers & Geosciences, 30(9-10), 1043–1053). A digital elevation model (DEM) with highest possible resolution is needed to run the model. To calculate the LS factor ACE2 3 arcsecond (\approx 90m) Digital Elevation Data was downloaded from http://tethys.eaprs.cse.dmu.ac.uk/ACE2/. The ACE2 Dataset has been created by synergistically merging the SRTM dataset with Satellite Radar Altimetry within the region bounded by ±60N. Over 11,000,000,000 pixels have been adjusted from the SRTM dataset using a unique network of control arcs of altimeter derived height data.

C and **P** factors

C and P factor values were adapted from Invest: http://www.naturalcapitalproject.org/InVEST.html

Invest	LULC_desc	С	Р	GLC 2000 class
28	Forest Closed hardwood	0.003	0.002	Tree Cover, broadleaved, deciduous, closed; Tree Cover, broadleaved, evergreen
40	Irrigated annual rotation	0.02	0.012	Cultivated and managed areas
44	Double cropping	0.02	0.012	Cultivated and managed areas
49	Row crop	0.02	0.012	Cultivated and managed areas
52	Field crop	0.02	0.012	Cultivated and managed areas
54	Late field crop	0.02	0.012	Cultivated and managed areas
55	Pasture	0.01	0.005	Herbaceous Cover, closed-open
		0.015	0.0085	Mosaic: Cropland / Shrub or Grass Cover
56	Natural grassland	0.005	0.002	Sparse Herbaceous or sparse Shrub Cover
57	Natural shrub	0.005	0.002	Sparse Herbaceous or sparse Shrub Cover; Shrub Cover, closed-open, deciduous
59	Flooded/marsh	0.002	0.001	Regularly flooded Shrub and/or Herbaceous Cover
62	Orchard	0.006	0.005	Mosaic: Cropland / Tree Cover / Other natural vegetation
66	Wet shrub	0.002	0.001	Regularly flooded Shrub and/or Herbaceous Cover





Climate change within Guangxi Province will affect not only people, but also species and ecosystems. Mitigation and adaptation activities, including ecosystem-based approaches within forest, can offer potentially large benefits. Furthermore, given their link with biodiversity, such activities can provide opportunities to make progress towards achieving the CBD Aichi Targets that are directly relevant for forest-based climate change mitigation and adaptation, in particular targets for reducing deforestation (Target 5), restoration (Target 15), protected areas (Target 11) and restoring and safeguarding ecosystem services (Target 14).

Spatial analysis can help maximise these synergies between climate change mitigation, adaptation and biodiversity conservation. For example they highlight the location of forest areas and areas of high carbon stocks, as well as their coincidence with areas that may be important for biodiversity, watershed management, soil erosion and population density. This report aims to provide decision makers and technical advisers with insights into broad range of spatial analyses which can contribute to identifying areas where synergies can be achieved for climate change mitigation, adaptation and biodiversity conservation.

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