GIS-assisted Modelling of the Historical Climax Forest in North East Yunnan (China) at the Beginning of the 18th Century

Ron HAGENSIEKER and Hans Joachim ROSNER

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Abstract

The focus of this study is a model of the spatial extent of an evergreen broad leaved forest (EBLF), indigenous in the NE Yunnan region, before the external impact of man. As a consequence of the growing demand for wood and lumber in the 18th and 19th centuries, there are today only a few historic EBLF's to be found in the study area. Since a representative plot of this historic forest type has been measured in past years by Chinese scientists (TANG et al. 2007), the habitats can be assumed to consist of three dominant tree species: 1. *Castanopsis delavayi*, 2. *Castanopsis orthacantha*, and 3. *Cyclobalanopsis glaucoides*. We have transferred these empirical observations to the study area. Using a GIS-based approach, we calculated the number of trunks in different constellations in the area. It further allows the calculation of the basal area, which is an important measurement unit in forestry and may also be helpful in future estimations of biomass. The basal area (BA) is expressed in m²/ha and represents the ratio of the trunks' cut surface to the free space in between the trees. It is measured at breast height, making the "DBH" (diameter at breast height) an important parameter. The longer-term goal of this study is to deliver the fundamental parameters to enable determination of the overall biomass of the study area at the beginning of the 18th century. For this reason, allometric methods have also been reviewed with regard to the EBLF of the study area, in order to create a foundation for prospective studies.

1 Introduction

1.1 Research Framework

This study was carried out within the scope of the project "Natural Resources in The Mining Areas of Yunnan during the Qing Period – Landscape Development, Environmental Change, Cartography, and GIS-based Webmapping" and its research framework "Monies, Markets, and finance in China and East Asia, 1600-1900: Local, Regional, National, and International Dimensions" (FOR 596, ROSNER & DIEBALL 2010). The project's main goal is to gain knowledge on the ecological impact of the copper mining and smelting in north eastern Yunnan during the Qing-Dynasty.

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As copper was mainly smelted with charcoal, it is assumed that Yunnan copper production was one of the main criteria for regional deforestation. It also has to be taken into consideration that population pressure increased during this period, leading to further deforestation as a consequence of intensive use of land for farming and of the requirement of wood for fuel.

Applying cellular automata, the processes of clearing and succession will be implemented in order to construct a balance model of extraction and forest regrowth. For further reference see (BRAUN 2010).

Fig. 1: Location of the study area: A buffer of 100 km has been drawn around the historical prefecture of Dongchuan (1820)

1.2 Study area

The historic prefecture of Dongchuan is a region of special interest, as hundreds of copper mines were located there (YAN 1957: 10, ZHU 1940: 21). It is to be pointed out that wood was brought from adjacent prefectures, up to four days' walk away (WU 1844). In our model this is represented by a buffer of 100 km around the outer borders of the 1820s Dongchuan prefecture (Fig. 1). It also has to be considered that there are some major natural features which may represent an obstacle, e.g. the Cháng Jiāng River and the overall steep gradient of the landscape, and these could possibly function as natural barriers. The study area is located on the Yunnan-Guizhou Plateau, which is dominated by river-carved gorges, geological faults, limestone, and karsts, including the Jinsha fault, which separates the Yunnan-Guizhou from the Himalayan Plateau (WINN n. d.).

The current landscape in the study area, which has been shaped by the influence of man, is dominated by alpine and sub-alpine meadows, which represent 35.6% of the surface area, evergreen coniferous forests (26.8%), and evergreen broad-leaved forests (16.2%) (GLOBAL LAND COVER FACILITY PROJECT 2000). This composition is a direct result of the processes mentioned above; to accommodate the demands of population growth and economic needs, alien tree species were imported and more farmland was created.

Current prefectures located in the study area are Kunming and Quijing in the south, Zhaotong and Bijie (of Guizhou Province) in the north east, and the autonomous prefecture Liangshan (of Sichuan) in the North West.

2 Modelling the Historical Climax Forest

2.1 Species in the study area

This study primarily relies on the research of LI & WALKER (1986), who described the natural climax vegetation as consisting of the four species *Castanopsis delavayi (CD), Castnopsis orthacantha (CO), Cyclobalanopsis glaucoides (CG) and Cyclobalanopsis delavayi*. This phytocoenoses typically appears between approximately 1500 and 2500 m altitude (LI & WALKER 1986: 376), which covers approximately 70% of the study area. Communities of higher altitudes were not taken into consideration in this study since their areal distribution is low and of no significant importance in determining the overall biomass. Also, below this altitude LI and WALKER do not expect tree species to be dominant. In their studies, TANG et al. quantify the relative basal area of the species as 45.4% *Cyclobalanopsis glaucoides*, 19.4% *Castanopsis delavayi*, and 28.9% *Castanopsis orthacantha* (TANG et al. 2007: 245). TANG et al. do not include the previously mentioned *Cyclobalanopsis delavayi,* which will also exclude this species from further analysis in this work. The study site of TANG et al. is located slightly SW of the research area used in this study: Mt. Huafu, 2450 m alt., 25°24'09" N, 101°28'18" E. It is described as being one of the last remaining historical climax forests in the area and it is used as a representative example of natural climax forests in this region.

Examining botanical databases (e.g. BIOSIS, Römpp online, FloraWeb, JSTOR), western literature, and internet documents resulted in only a small amount of habitat information on these species. eFlora's subproject "Flora of China" (FOC) can be considered to be the only source on these habitats, since most of the information used relies on their work (HUANG & ZHANG, BARTHOLOMEW 1999).

Castanopsis delavayi and *Castanopsis orthacantha* can be found on loamy soils and soils with the necessary amount of moisture which are acidic or pH-adjusted (HUANG, ZHANG & BARTHOLOMEW 1999: 18). However, they differ in altitudinal distribution, with *Casta-*

nopsis delavayi settling primarily between 1500 and 2800 m, while *Castanopsis orthacantha* can be found higher up, at 1500-3200 m (ib.: 18, 22).

Cyclobalanopsis glaucoides is found between 1500 and 2500 m (HUANG, ZHANG & BARTHOLOMEW 1999: 96). Information on soils is also rare. LI and WALKER (1983: 379) point out that red earth and humus are advantageous factors.

2.2 Environmental factors

The suitability for the three different species was calculated using data about habitat information, derived from the "Flora of China" (HUANG, ZHANG & BARTHOLOMEW 1999), information about soil distribution extracted from the Harmonized World Soil Database HWSD (FAO 2006), and a DEM (JARVIS et al. 2008). In addition, exposure to monsoon precipitation was included as a factor which adjusts the altitudinal distribution of the three species.

2.3 Processing

Firstly, three raster layers were created with binary information, to represent the occurrence of the three species mentioned above. To achieve this, several steps had to be initiated on the basis of Boolean algebra. In the first step, three binary image masks were generated concerning the soil compatibility of the three species CD, CG, and CO.

Using this information, a spread sheet was then created to document the possible compatibilities in tabular form. The columns bore the three species CD, CG, and CO; the rows listed all HWSD-soil types of the region. Compatibility was then estimated by comparing soil attributes given by the World reference base for soil resources 2006, and the habitat requirements defined by HUANG, ZHANG & BARTHOLOMEW 1999. This table was attributively joined in ArcGIS, linking it to the available HWSD soil map, thus generating spatial information on patches of suitable soil. Subsequently, the shape files were converted to raster format in order to allow further processing.

Three more layers were created to represent the altitudinal distribution of the three species. For complete distributional limits, see chapter 2.1. For CD we used minimum data from HANDEL-MAZZETTI 1929. This led to specific distributions, varying between 1250 and 3200 meters.

The most appropriate way to include the monsoon factor is by considering its effect on windward and leeward slopes: it reduces the capability of trees to grow on slopes with northern exposition, while on slopes facing south it provides beneficial conditions (Table 1). For example, according to FOC data, *Cyclobalanopsis glaucoides* settles between 1500 and 2500 metres. In this study, the data for *Cyclobalanopsis glaucoides* was modified to its growing at 1500-2000 m on northern expositions, 1625-2250 m on "neutral" slopes facing west or east, and between 1750 and 2500 meters with southward exposition. It should be noted that this classification is based mainly on the interpretation of similar monsoonal effects which have been observed in comparable areas (SCHULZE & HESSBERG 2008).

Table 1: Modified altitudinal distribution of the three considered species. Modification is based on a cautious estimate of monsoonal effect. Lower limits were changed in steps of 125 m, upper limits in steps of 250 m. As a consequence, the altitudinal distribution spreads on windward slopes.

Exposition	**North**		**West / East**		**South**	
Growth (height in m)	**min**	**max**	**min**	**max**	**min**	**max**
Cyclobalanopsis glaucoides CG	1500	2000	1625	2250	1750	2500
Castanopsis delavayi CD	1250	2300	1375	2550	1500	2800
Castanopsis orthacantha CO	1500	2700	1625	2950	1750	3200

These effects were included by creating an aspect raster from SRTM-data (JARVIS et al. 2008). This information was then subdivided into three layers to cover the differing monsoon effects. They were then used to clip the SRTM. This resulted in one layer per species and exposition type. With every species being represented by one Boolean layer, covering slopes of every aspect, these nine layers were then overlaid, giving every species a single layer representing its compatible altitude.

The resulting three maps were combined with their corresponding binary distribution, based on soil compatibility, to create a layer with the spatial distribution for each species (Fig. 2).

In the final step, the three remaining layers (CG Bin, CD Bin, CO Bin), were combined to generate a map of the overall distribution of CG, CD, and CO.

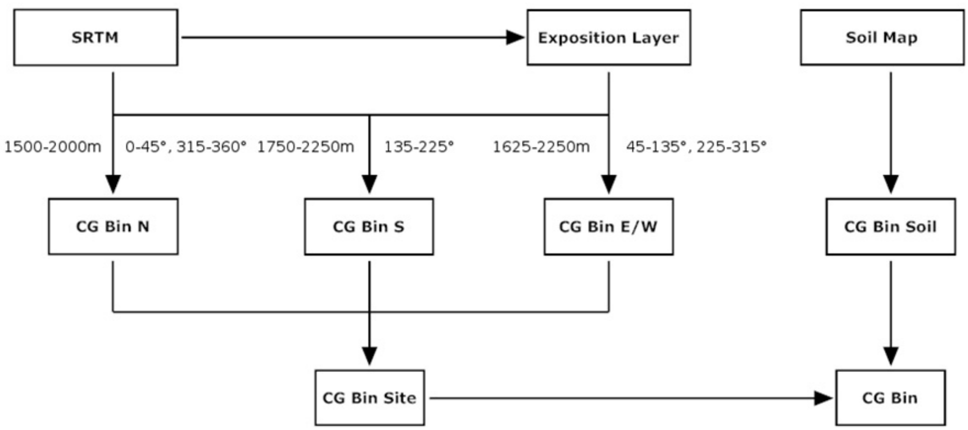

Fig: 2: This figure illustrates the steps necessary to create a raster map of the species distribution of *Cyclobalanopsis glaucoides*. The combination of maps was established using the Raster Calculator function of ArcGIS.

Further consideration was given to the question of whether to include historical climate as an additional factor, in particular regarding the Little Ice Age. However, recent historical studies on temperatures of the region do not show severe differences between the climatic conditions of the 17th and the 20th centuries (GE et al. 2008, LIU 2005).

3 Results and Discussion

The result is an overall tree coverage of 57.57% for the study area. This differs slightly from the values published by LING (1983), who estimates values of 65.8% (Yunnan) and 62.8% (Sichuan) for the year 1700 (Fig. 3).

The most dominant tree of the study area is CG, which is also typical for EBLF of the area (LI & WALKER 1986: 378, TANG & OBSAWA 2009: 344). In our model this is mainly due to CG being more euryoeicous regarding soil types.

TANG & OBSAWA (2009: 344) give data concerning the number of trees in connection with their diameter at breast height. This information was transferred to the study area to estimate the composition of the constructed forests and their biomasses (see Table 2). Proper allometric formulae on EBLF's have recently been found and will be used for further research (LUO 1996).

With regards to table 2, it has to be considered critically whether the calculated DBH's for those climax forests which are lacking in one or more species are generally realistic. This problem arises because, in her works, TANG only took measurements in forests consisting of all three species, with CG playing a dominant role. To what extent the removal of CG has an effect on tree numbers and sizes in a forest consisting of solely *Castanopsis*is is basically not predictable.

The dominance of CG can be further questioned by assuming TANG's plot not to be truly representative for the whole study area. This is due to the fact that while the Flora of China describes the highest situated edge of CG as being 2500 m, it in fact dominates the plot of TANG et al. at a height of 2450 m, which seems exceptional.

Further, it has to be assumed that, especially in borderline areas, there are almost certainly other species interfering with the three species, and these other species have not been examined in this study. Leaving this aside, historical soils have not been processed yet, as this would have been a very complex and uncertain procedure.

For future research, allometric calculations will be used to estimate the net primary production of the above-mentioned forest types. We aim to prepare a model for biomass (re-)production in order to calculate the (in-)balance between forest use and regrowth, concerning the historical copper production in the study area.

An alternative approach to this very specific dataset could be to rely on more general data on forest composition. This would also make the acquisition of allometric data easier.

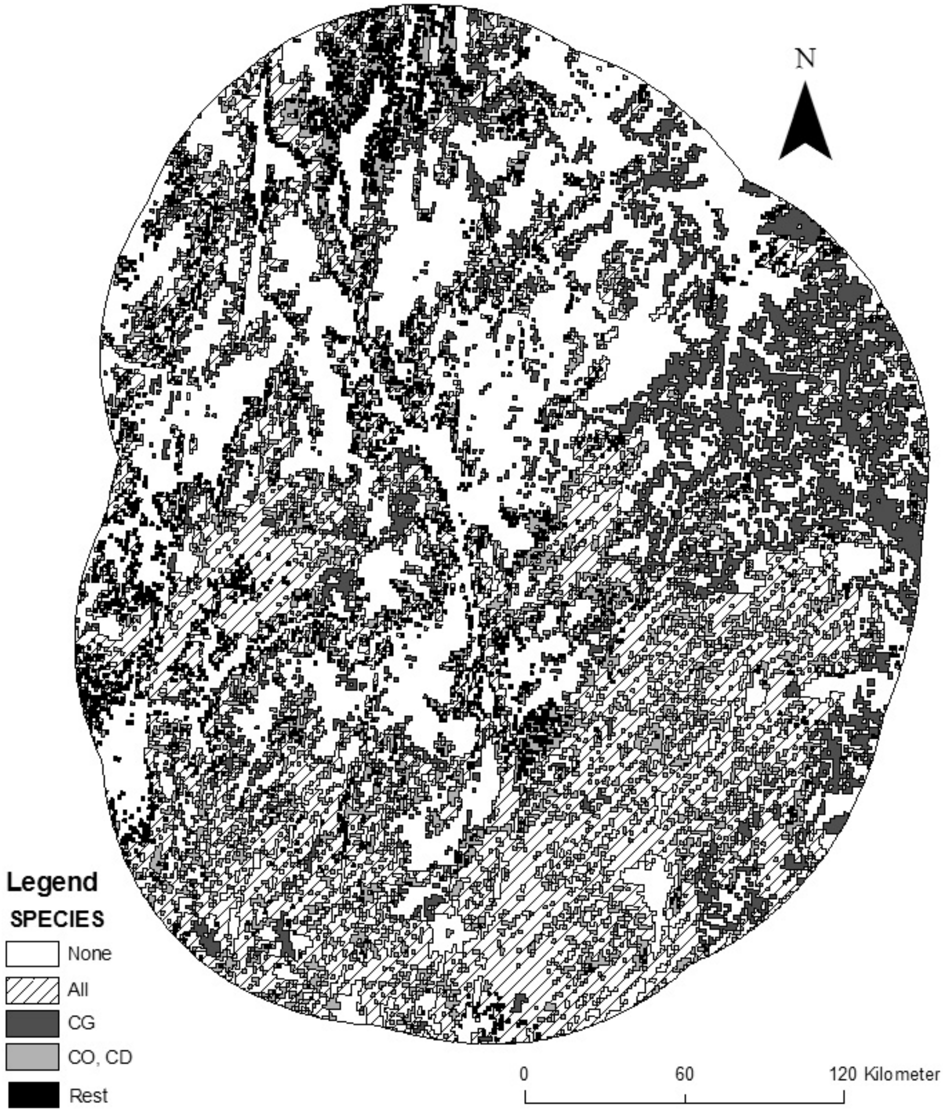

Fig: 3: The modelled climax forest of the study area. The three most frequent categories (All, CG, and CO, CD) occur in 57% of the overall study area

Tab: 2: Number of trunks in the study area with Basal Area (BA) and class DBH > 100 cm. Differing relations (BA CD > BA CO) are due to interpretations of the data of TANG et al. 2007.

Forest type	BA CG in km²	BA CD in km²	BA CO in km²	Trunks CG in mil.	Trunks CD in mil.	Trunks CO in mil.	BA sum	Trunks sum in mil.	Trunks DBH > 100cm in mil.
All	193	117	85	1092	1274	2015	395	4381	171
CG	146	0	0	828	0	0	146	828	65
CO, CD	0	76	56	0	831	1314	132	2145	56
CO	0	0	37	0	0	866	37	866	12
CD	0	35	0	0	388	0	35	388	17
CG, CD	5	3	0	31	36	0	9	67	4
CG, CO	1	0	0	4	0	7	1	11	0
	345	231	178	1954	2529	4201	755	8684	326

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