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Karst Geomorphology

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**KARST GEOMORPHOLOGY AND ITS AGRICULTURAL IMPLICATIONS
IN GUIZHOU, CHINA**

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In Guizhou Province, China 73% of the land is on carbonate rock, and hence there are large areas of karst. The agro-ecological effects of karst development include soils characterised by high calcium, low alkalinity and poor fertility. Soil formation is slow, resulting in thin cover, and there is severe erosion. Large areas have steep slopes, and there is a non-uniform double karst water-bearing system consisting of solution pores, fissures and conduit spaces. The area has a low critical value range with respect to natural disasters, low environmental capacity and low agricultural output.

Three agro-environmental types are identified: the dry agro-ecological environmental system of the fengcong-depression karst; the dry and wet dry agro-ecological environmental system of the fenglin-depression karst; and the wet dry agro-ecological environmental system of the fenglin-plain karst.

As the karst and the associated environment changes from plateau to deep gorge, so does the appropriate agriculture for that area change. Therefore, eco-agriculture must be developed to coordinate the structure of the eco-economic system, to encourage its orderly development for high output, high quality, high effect and low consumption. The agricultural effort should be diversified to produce reasonable yields of grain and cash crops according to different environments and market needs.

KEY WORDS: Karst Landform, Agricultural Implication, Guizhou.

INTRODUCTION

Guizhou Province in southern China is located at the heart of the East Asia Karst, one of the three largest areas of almost unbroken karst in the world. The Guizhou carbonate rocks are a 6,200-1,100 m sequence in depth and cover 130,000 km², about 73% of the provincial area (Sweeting, 1986). A suite of typical karst landforms is well developed on the complex structural background and in the favourable tropical-subtropical environment. The province contains 87% plateau-mountains, 10% hills and 3%

basins. The agricultural implications of karst are related to the distribution and combination of the variables that control karst development (light, temperature, air, water and soil). In addition, the geomorphic type and structure also gives rise to changes in agricultural conditions and hence agricultural activity and planning (Yang, 1992).

**AGRO-ECOLOGICAL EFFECTS OF KARST
DEVELOPMENT**

The soil is characterised by increased calcium, decreased alkalinity and poor natural fertility. Rocks supporting the karst of Guizhou are mainly pure limestones and dolomites (90-99%), and thus have low amounts of insoluble residuals. Water, soil, air, plants and animals must be characteristic a calcium-enriched environment. It generally has more Ca, Mg, Se, Si, Al, Mn, Fe & Be, and less P, I, S, C, N & B. Surface and subsurface water are of a HCO₃⁻, Ca and Mg type with high hardness (9-16H°) (Gemerny) and temperature range (12-18°C), which effects field irrigation and thermophilic crops such as rice.

The process of soil formation is slow, with thin coverage and severe erosion. Over 90% of carbonate rock dissolves, at a rate in the order of 62 mm/1,000 years. The insoluble materials which remain as weathering residuals and are available for soil formation accumulate at a very slow rate 0.25 mm/1,000 years. As a result, soils are primarily of the immature lithological types such as red or yellow clays, and lime-soils. Soil cover is usually of less than 300 mm. The chemical, physical and ecological features of the soil are poor, and there is a clear interface between rock and soil resulting in poor coherence. Thus, it is easy for heavy rain to cause soil erosion and mass movement. Erosion surfaces

and bare rock account for 28% of the province at present and are increasing at a rate of 0.17 ha/km² each year.

There is a large area of land with steep slopes. As a result of neotectonic uplift and trunk river incision, the karst has developed vertically, giving the high relief. The hill slopes of fengcong and fenglin karst are normally over 42-47°. In the province, 31.9% of the land has a slope greater than 25°, 69.4% has a slope greater than 15° and only 8.6% a slope less 8°. In the 26 poorest counties in Guizhou, 67% of the land is arable and 33% is steeply sloping. Once deforestation occurs in these areas, the degree of slope becomes a key factor in soil erosion. 80% of the middle and low-yield rice and dry crop land in Guizhou is located on slopes, making it vulnerable to erosion from poor agricultural practices.

The karst aquifer is a non-uniform double water-bearing system consisting of solution pores, fissures and conduit spaces, connecting both surface and underground catchments. Because of the unique properties for water discharge, flow and recharge, the storage varies widely from place to place. Although annual rainfall reaches 1,200 mm, most of the water disappears underground via sinkholes and dolines. The result is that «water becomes as expensive as oil» on the surface but there is adequate underground water available. However, even along the same aquifers, some wells can be dry and some wet. This complicates an aquifer development and utilisation for domestic water supplies and irrigation.

Critical values and range for natural disasters are low, but the response is sensitive. Slopes rapidly become bare-rock within decades after deforestation. In contrast, it will require many more decades or even centuries to reforest the hills. Crop yield is reduced about 20% in droughts, which have occurred on average once every 5 years in the past 500 years. Drought frequency is 18-30% higher than in non-karst areas under the same conditions. Drought can seriously effect crop production, for example, in the Xingyi region which has 121 waterlogged depressions with a total area of 1,556 ha production is significantly reduced if there is no rain for 20 days.

Environmental capacity and synthetic output are low in these areas. The proportion of farmland within the karst is low. The fengcong karst, for example, has only 5-10% farmland. Together with the other inherent shortcomings of karst as discussed, grain yield is normally under 3,750 kg/ha. Four districts with typical karst landforms, Anshun, south Guizhou, southwestern Guizhou and Bijie, have respectively 3,075, 4,425, 3,375 and 2,700 kg/ha yields of grain, which are considerably less than yields from non-karst areas. The result is that the number of people that can be supported by an area of karst is much less than can be supported by the same area of non-karst.

AGRO-ENVIRONMENTAL CLASSIFICATION OF KARST LANDFORMS

Karst leads to regional variety and difference in agro-ecological structures and types. Morphometry and mor-

phology consisting of positive and negative forms, and combinations (Xiong, 1992) can be used to classify the agro-environmental types of the karst landforms in Guizhou.

Dry Agro-Ecological Environmental System of the Fengcong-Depression Karst

This type of karst, a combination of clustered cones and depressions, valleys and gorges, is normally developed in areas with higher available relief. The area of positive forms is greater than that of negative forms. Cones are connected at a common base with summits having heights from 100 to 250 m. The subsurface karst is dominated by many vadose caves developed under low water-level conditions. Depression, with variable sizes, show polygonal features. Their floors are at different heights far from the local base-level beneath and lower towards the land-slope direction. Dolines or sinkholes are formed in the centre of deep and bare depressions at higher levels, or at the rim of shallow and flat ones, covered by weathering residuals and slope washes, at a lower level. The valleys, with open features, have mainly originated from depressions developed along the local geological strike, some appearing as inherited fossil drainage. Most of them contain flat, bare rock floors without modern streams, but some with superficial sediments of weathering residual and slope wash in which dolines and sinkholes have developed. Gorges of 300-700 m deep are produced by downcutting of trunk rivers in response to neotectonic uplift. With high gradient and no alluvium, they occur with three types of cross-section: V-shaped with straight slopes, box-shaped with vertical slopes, and fracture-shaped with convex slopes. The uplift around the gorges has lowered the water table and causing karst rejuvenation, and giving rise to many deep, bare depressions.

The characteristics of this agro-ecological environment are bare karst, vegetation mainly the evergreen *aestilignosa*, lime-soil, intense seepage, deep underground water, dry land surface, thin soil cover with intermittent distribution and multiple dry and flood depressions. Together with drought in the dry season and floods in the wet season this leads to a depressed agriculture. The failure to develop satisfactory water management has lead to variable water supply and poor soil quality. Hence at present the area supports only simple agriculture with low and variable yields.

Dry and Wet Agro-ecological Environment of the Fenglin Depression Karst

This karst is a combination of isolated cones and open depressions or broad U-shaped valleys, and is normally found in areas of decreasing relief. The area of positive forms is almost the same as that of negative forms. This transitional system lies between the fengcong-depression karst above and the fenglin-plain karst below. Cones are

isolated and scattered around depressions or valleys. Their summits are relatively uniform in height, 100-200 m. Underground water at shallow depth. Depressions with polygonal features are large and shallow. One of the most striking features is the uniformity of the level of the floors which are covered by thin weathering residuals. In these polygonal depression floors dolines and sinkholes are developing. The valleys in the karst, with open features, tend towards local base-level. There are many springs and resurgences along valley rims, and many surface streams and small flood plains on the valleys floors. It is concluded that the valleys are produced in two ways: by the merging of depressions along the geological strike at the base-level as a sort of base-level polje (Ford & Williams, 1989), or by widespread lateral planation resulting from accumulation of alluvial materials.

The features of this agro-ecological environment are bare karst, eleuthrodactylous vegetation, yellow and red-yellow clay soils as well as lime-soils, a few surface streams, medium-depth underground water with uneven distribution. Functionally, this leads to an increase in the land available for rice-growing, but the land is still mainly used for dry crops.

Wet Agro-ecological Environment of the Fenglin-Plain Karst

This karst is a combination of sparse isolated cones and vast flat plains, basins and tablelands developed in areas of low relief. The area of positive forms is less than that of negative forms. The cones form residuals or *inselbergs* 50-150 m high, which may rise from the alluviated or karst-planed rock surfaces. Foot-caves are common at the bases of cones. There is a high rate of exchange between surface and subsurface water in this karst. The plains are covered with thin residual soils or nothing, and display a «karst peneplain» level bedrock structure. They are of considerable size with flat features and lying near the local base-level. The river systems have alternating surface and underground sections which form numerous karst lakes on the plains. Broad basins mainly produced in the neotectonic fault-valleys of the «karst peneplain» are bounded by fenglin and some fengcong karst. Within the basins are superficial sediments including alluvium, lake-bed peat and slope deposits. Off the central basin, the spatial distribution of karst landforms shows vertical zoning. The basin catchments are closed and springs and resurgences along the basin edges feed rivers which give basin floor with lateral planation and result some towers. The tablelands are mainly developed on the neotectonic fault-upland, the «karst peneplain». Where the land surface is very flat and vast and covered by thin residual soil. There are many isolated residual cones several tens of metres high, and there are alignments of recent dolines several tens of metres wide developed on the surface due to lowering of the water table.

The characteristics of this agro-ecological environment are half-bare karst, with vegetation mainly *laurilignosa*, yellow soils, well developed underground and surface river systems, shallow, uniformly-buried underground water, so-

me thick soils, higher capacity for water conservation. Functionally, there is a majority of flat rice fields, plus dry crop land, well developed water conservation, well-structured agriculture and stable crop yield.

AGRO-REGIONAL STRUCTURE OF KARST LANDSCAPE

The subtropical karst landscape of Guizhou is characterised by a plateau-gorge structure which is a major factor causing regional differences in agriculture. The regular geomorphic series of fenglin-plain → fenglin-basin → fenglin-valley, fengcong-valley → fengcong-depression → fengcong-gorge. The gorges arise from the plateau division and can be divided into two regions, the upper reach and lower reaches of the gorges (He, 1986). The geomorphic changes are accompanied by a change from wet, wet and dry and dry climates.

The plateau region, with a majority of planation surfaces (peneplain) in the centre, includes Weining, the Hezhang areas of northwest Guizhou, and the most central parts of Guizhou. The rolling surface of the plateau is well-preserved, with low relief, usually 50-150 m. A combination of many cones, vast flat plains, basins, U-shaped valleys and depressions gives rise to shallow-covered fenglin karst landscapes such as fenglin-plain, fenglin-basin, fenglin-valley and fenglin-depression. These areas are normally karst hill-plain and hill-basin in land type, with zonal and red soils on a karst weathering crust. The soil cover, composed of regional yellow and red-yellow soils, is thick, with little erosion. Vegetation is zonal and changes with altitude. Shallow-buried groundwater, 0-20 m deep, with diffuse flow, is evenly distributed and easy to exploit. Access to both surface and underground water is easy, and, as result, the condition and level of water conservancy in this area are very good. The open topography allows lots of light and high average temperatures, is suitable to sunlight-loving crops. Cultivation is by irrigated agriculture, primarily large-scale flat rice fields and terraces, suitable for agricultural machinery. The cultivation index is over 30%, suitable for agricultural scale management. The long history of cultivation, the convenience to traffic, and the concentration of towns all help the development of an agricultural commodity economy. The region is well developed in terms of agriculture relative to other areas in Guizhou.

In contrast, most other parts of this province are located in gorge regions and valley slopes dissected by rivers, with high relief, normally over 500 m. A combination of large-scale cone karst and deep valleys and depressions gives rise to bare fengcong karst types such as fengcong-valley, fengcong-depression and fengcong-gorge. These form subtropical rocky hill-depression, valley and gorge land types and have vertical differences in light, temperature, water and soil. The statement «There are four seasons on a mountain and different weather in five kilometres» describes the variable nature of this environment. The high relief with narrow indentations causes a short duration of

sunlight, low average temperatures and considerable soil erosion. These areas mainly contain deep depressions and rocky hills with non-zonal calcareous soils on slope wash residuals. The land consists generally of immature lithological soils on slope crop land and dry crop land. Underground water, with conduit flow, is deeply buried, with the water table 40-300 m below small dolines, and thus difficult to exploit. The land is subject to specific karstic droughts and topographic floods. As a result, the agro-ecological environment is characterised by dispersed crop fields and bad water conservancy, underdeveloped irrigation, frequent drought and flooding, and low capacity for humans. The main features of cultivation are hand-irrigated farmland, hill farmland and hillside terraces which are difficult for agricultural machinery. However, the range from the gorge floors to the plateau enable a vertical distribution of agriculture allowing a great variety of crop types.

AGRICULTURAL DEVELOPMENT-MANAGEMENT IN KARST AREAS

An eco-agriculture must be encouraged to coordinate the structure of the eco-economical system and its orderly development. To achieve high crop yields and quality with low consumption, it is necessary to adjust the structure of rural industry. This may be achieved by gradually decreasing primary industry and increasing secondary and tertiary industry. By developing industry before and after agricultural production, it is possible to change the dependence of humans on the land in low-capacity karst environments. Crop farming must be changed from the sole production of grain and diversification promoted. The mixed grain and cash crop production should be introduced in accord with the differing ecologies of the karst land and with market demands.

Eco-agricultural cells should be set up, incorporating eco-economical villages. A poor village in the fengcong-depression karst of Guizhou, for example, could be set up on a stereo and multi-layer eco-economical pattern within the depressions variety of land types. For example, the depression floor is normally flat with thick soil cover suitable for grain and cash crops. The foothills are good for dry crops, fruit trees and medicinal materials. The hillside would be beneficial for fast-growing fuel trees, fruit, medicinal materials, and other forests. The hill-tops should be planted with a ground covering vegetation to hold rainwater, decrease slope erosion and increase the duration of water percolation and storage. A depression developed in this way would form an eco-environment with economic efficiency and ecological balance.

It must be stressed that during the implementation of eco-agriculture, attention must be paid to soil erosion and the «rocky desert processes» which destroy the basic conditions necessary for sustainable agriculture. Land unfitted for farming, (slopes over 25-30°), should be planted with forest. This investment would greatly improve the middle-

yield land, increase the output of high-yield land, and help in the development and management of low-yield land. It is also necessary to develop such non-food producing steeply sloping land, in order to allow for an increase in the living space available to farmers on the low relief land.

DESCRIPTION OF AND RECOMMENDATIONS FOR AGRICULTURE IN THE KARST REGIONS OF GUIZHOU

The karst mountains and hills of East Guizhou are characterised by more hills, large valley basins, a warm, humid climate, rich water sources, higher irrigation level and thick soil cover. This is a developing area, mainly for agriculture with integrated forests, herds, and fishing. The low mountains and hills in this area are suitable for the development of crops such as rice, oil tea, tung oil, and stillingia. Mts Fanjing, Leiging and Yuelang in the west, with discontinuous distribution of land, wide range in altitude, and vertical climate change due to intense fluvial dissection, should be used for forest cover to retain water for to improvement of agricultural conditions in the low land areas.

The karst of North Guizhou is more mountainous, has fewer strathes and deep valleys. The great range in altitude leads to a wide difference in natural conditions. In the river valleys, with short frost and snow periods resulting in a long growing season, crops can be grown three times a year. The crops suitable for this region are rice, sugarcane, citrus, longan, litchi and summer orange. In the temperate and humid hills, crops can be planted twice a year for rice, corn, millet, wheat, rape, tung oil, arbovitae and China fir. The humid lower-middle mountains there are good conditions for growing dry crops such as pine, China fir, Nanzhu, pear and apple. In the cool, humid middle mountains lacquer trees can be grown, and crop and livestock farming would be possible in some parts of this region.

The karst hill-plateau region of Central Guizhou is the main agricultural region of this province. The denudation plain of the Shanpan Period provides favourable conditions of temperature, water and land. This is a well developed area, mainly for grain production, with integrated farming, forest and livestock production. In the intermountain basins and fluvial plains, the cultivated land has a thick soils and good irrigation. The conditions are excellent for double-cropping of rice, rape, wheat and oil-tea camellia. The rolling hills and mountains could be used to develop timber and fuel forests, and for the grazing of livestock.

The conditions on the karst hill mountain-plateaus of South Guizhou are suitable for agriculture, forests and livestock. The river basins of Hongshuihs and Nanpanjiang have low altitude, high temperatures, negligible frost and snow, plentiful rainfall and a long growing season. Subtropical cash crops, such as sugar cane and Chinese wisteria, and fruit, such as summer orange and banana, grow well. There is the possibility of double-crop-

ping rice and oil/wheat in the hills and basins. The transition zone from valley slope to mountain plateau provide excellent prospects for growing tung oil trees and Yunna and Mawai pines.

The karst mountain-plateau region of West Guizhou is characterised by higher altitudes, lower temperatures, poor soil and a short growing season. Grain production is not as high as in other regions. There is a large amount of barren land and hills with rich pasture and forage, making it suitable for establishing herds, and planting forests. The conditions are perfect for growing cool-climate crops such as potato, beet, and temperate fruits and at higher altitudes, lacquer trees.

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