

The Temporal and Spatial Scales of Arable Land Loss and its Impact in Guangxi, China: A Commentary

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ABSTRACT

Cropland abandonment because of rural depopulation or policy interventions has become a key issue in Chinese mountainous areas. One such region is the Guangxi Karst Mountainous Area (GKMA), a zone where more than 59% of total land area is hilly and plots of arable land of a commercially-viable size are almost non-existent. The rugged terrain and land fragmentation in upland karst areas result in the scarcity of land suitable for cultivation. Although depopulation and declining agriculture since 2000 within the GKMA have led to vast areas of abandoned cropland, the spatiotemporal distribution that underlies this pattern, as well as its causes, remain little understood. Five human-related causes have contributed to accelerated soil loss in the rural karst mountainous areas of Guangxi. These immediate causes include road erosion, house construction, steep slope cultivation, tourism development, and animal trampling. Root causes are also at play. Geomorphic features (slope, elevation) also influence the distribution of settlements. Settlements with different degrees of distribution are accompanied by spatial differences in cultivated land resources, which lead to differences in the sufficiency of cultivated land resources. In this paper we provide an overview of the magnitude of the problem of arable land loss. We draw on statistical data about the areas of arable land, meteorological data, topographic data, and socioeconomic data from 2010 to 2018, to classify the concentration and dispersion of settlements and analyze the spatial distribution and the spatial agglomeration of the cultivated land.

Keywords: karst, terracing, livelihood, settlements, poverty alleviation, demography, infrastructure, indicators, peri-urban

CONTEXT AND SETTING

Guangxi Zhuang Autonomous Region (GZAR) is a less well-known part of China. Its coastline abuts the South China Sea and its neighbour to the west is the province of Guizhou (Fig. 1a).



Fig. 1a. The location of Guangxi Zhuang Autonomous Region within China and the inset shows more details Fig.1b. the extent of the mountainous areas GKMA (in brown shading) located mainly in the west and north

Cropland abandonment because of rural depopulation or policy interventions has become a key issue in Chinese mountainous areas. One such region is the Guangxi Karst Mountainous Area (GKMA), a zone where more than 59% of total land area is hilly (Fig.1b.) and plots of arable land of a commercially-viable size are almost non-existent (Fig. 2a). Much of the land in the GKMA is too rocky to cultivate on a commercial scale. There is subsistence cropping of corn and sweet potatoes but many households rely on assistance from the Poverty Alleviation Bureau.



Fig. 2a. Rocky land is unsuitable for cultivation but some food plants can be grown between the outcrops (2b). Any flat, rock free areas (2c). are highly sought after

On some slope land that is not too rocky or too steep farmers have developed complex terraces to allow crop production, especially rice (Fig.3a,b,c).



Fig. 3 a,b,c Over the centuries, farmers have constructed terraces that transform the steep hillsides and allow food crops to be planted. Fig 3b is an aerial view from 5,000 m

So called *rocky desertification* (Fig. 4) is another limiting factor. By definition, desertified land is 'previously productive land that has become degraded by misuse' (Shi, Yang & Li, 2019).

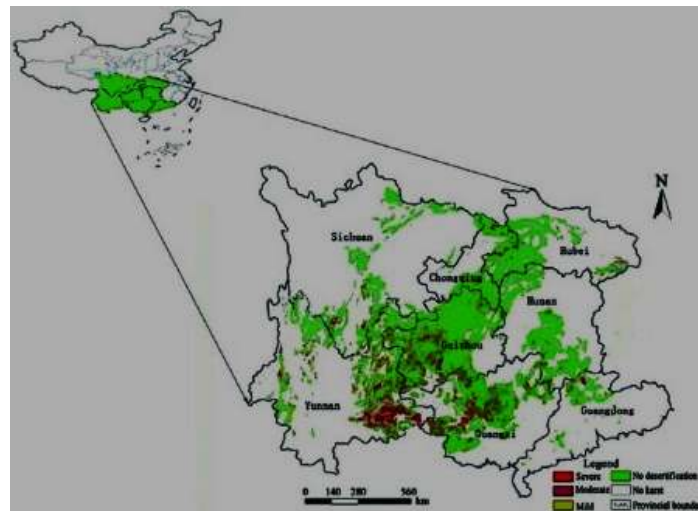


Fig. 4 Sketch map showing the distribution of karst landscapes (green) and the places where rocky desertification is found. Note that Guangxi has some areas that are classed as Severe or Moderate

Although depopulation and declining agriculture since 2000 within the GKMA have led to vast areas of abandoned cropland, the spatiotemporal distribution that underlies this pattern, as well as its causes, remain poorly understood (Hang and Song, 2020). The rugged terrain and land fragmentation in karst areas result in the scarcity of cultivated land but overexploitation has exacerbated soil loss and reduced productivity.

APPROACH ADOPTED AND TOOLS USED IN THIS STUDY

This study in Guangxi Zhuang Autonomous Region (GZAR) draws on arable land data, meteorological data, topographic data, and socioeconomic data from 2010 to 2018. We employ *kernel density*¹ to classify the concentration and dispersion of settlements, and divide the area into grids of 1×1 km. We analyse the spatial distribution of the balance of cultivated land with the *Lorenz curve*², and uses *Moran's I*³ to analyse the spatial agglomeration characteristics of cultivated land area. Land-use change is not a unidirectional process, and a specific land-use type may change into or from other land-use types (Han, Yang, Song 2019). This study also uses the *land-use transfer matrix* to indicate the degree of conversion of cultivated land and other land types, and quantitatively evaluates the factors affecting the distribution of cultivated land and its temporal and spatial evolution with geographical detectors such as contour maps and aerial photography and satellite imagery (Hu et al., 2019). A Digital elevation model (DEM) was used to separate the land use types based on steepness of the slopes, elevation and degree of relief.

¹ Kernel density estimation is the process of estimating an unknown probability density function using a kernel function. While a histogram counts the number of data points in somewhat arbitrary regions, a kernel density estimate is a **function defined as the sum of a kernel function on every data point**.

² In economics, the Lorenz curve is a graphical representation of the distribution of income or of wealth. It was developed by Max O. Lorenz in 1905 for representing inequality of the wealth distribution. The extent to which the curve sags below a straight diagonal line indicates the degree of inequality of distribution.

³ Moran's I is a **correlation coefficient that measures the overall spatial autocorrelation of your data set**. In other words, it measures how one object is similar to others surrounding it. If objects are attracted (or repelled) by each other, it means that the observations are not independent

Box 1 shows the full range of variables and indicators used in this study. This set has been used in other studies and is robust and relatively easy to use. Although monitoring population growth rates (both positive and negative) in fragmented karstic landscapes is not so simple, it is very important to do it because of peoples' dependence on limited natural resources that occur in small isolated pockets.

High population densities demand high resources and can also pose threats to the unique biodiversity due to overexploitation of key inputs like water, fuel for cooking and heating, forage for livestock etc.(see discussion below about grazing/browsing livestock). Too much pressure can lead to habitat degradation. In addition, growing population in relatively resource-rich locations exacerbates land-use conflicts, environmental degradation, and competition for scarce resources (Chi and Ventura, 2011). Examination of literature over the past 40-50 years shows that there has been a fundamental shift in peoples' response to periodic natural disasters like droughts, floods, landslides etc. Many households in the GKWA raise livestock on rangelands woodlands and forests as an income supplement and to provide milk, meat, fiber and hides etc for home consumption. Livestock are owned by the individual householder but the land on which they graze/browse is held as a Common Pool Resource (Ostrom,1990) and is owned collectively. Restraints on the number of livestock are not too strict and over-utilization can occur often. In the past there were arrangements in place to offset the shortfall in forage, water and fuel supplies. Areas were set aside (by mutual agreement) and held in reserve. During good seasons flocks and herds were grazed at a distance from the settlement and were brought back to graze/browse on the "reserve" near to the settlement when the seasonal conditions were bad. This system prevailed during the "collectivization phase" after the founding of New China and was superseded by the incentive-driven Household Responsibility System.

Box 1 Principal influential variables with indicator value

Variable	How measured?	Indicator value	Remarks
Population density (persons per km ²) ⁴	Official documents, statistical reports	High	Populations are rising in coastal city/ports and in places where high speed rail has been installed.
Distance from a railway station (km)	Site specific but includes both passenger and freight lines	Moderate	Mobility and access to markets is highly valued
Distance from a port (km)	Site specific	Moderate	Easily calculated
Distance from proclaimed Free Trade Zone (km)	Nanning Free Trade Zone	High	Port cities of Qinzhou and Fangchenggang are part of the Free Trade Zone and are destined to undergo rapid growth
Distance from Provincial capital (km)		Moderate	
Distance from a numbered road (km)	Site specific (excludes unnumbered local 'feeder' roads)	High	County-level and national level
Density of road net (km/km ²)	Affects level of land fragmentation	High	Derived from maps. imagery
Proportion of basic farmland (%)	From official statistics	High	Basic farmland in China as a whole is set at an irreducible minimum area. Land cannot be re-zoned for other purposes
Proportion of area under ecological protection (%)	Land in a 'set aside' land bank. Retired from cropping but often planted to trees	High	This area has risen sharply, especially on slopeland as part of National "Grain for Green" program
Slope (degree)	Slopes in excess of 20 degrees must be terraced	Extremely High	Tree crops, including <i>Eucalyptus</i> plantations
Degree of relief,	Calculated, with a value of 143 classed as <i>High</i> and a value of 0 as <i>Low</i>	Extremely High	There is much land fragmentation in the uplands
Elevation (m).	From topographic maps and GPS	High	
Distance from water source (km)	Site specific but includes reservoirs, dam, rivers, lakes	High	Above-ground streams are less common in karstic landscapes
Annual precipitation (mm)	Data from Bureau of Meteorology	High	Rainfed crops depend on adequate precipitation or have access to supplementary irrigation from groundwater or other artificial sources

Restraints on the number of livestock are not too strict and over-utilization can occur often. In the past there were arrangement in place to offset the downturn in forage, water and fuel

⁴ People census data in Guangxi Available at: <https://finance.eastmoney.com/news/1365,20180122824479357.html>

supplies. Areas were set aside (by mutual agreement) and held in reserve. During good seasons flocks and herds were grazed at a distance from the settlement and were brought back to graze/browse on the “reserve” near to the settlement when the seasonal conditions were bad. After the implementation of the Household Contract Responsibility System, ownership of livestock passed to the householders but the land to support them remained in care of the ‘collective’ (Tilt,2008). This situation regarding reserves, and their use, might be as illustrated in Fig. 5. In many areas the situation is a good example of the ‘Tragedy of the Commons’ (Hardin, 1968) because no one took responsibility and every individual household could benefit by exploiting the resource before their neighbour did. To do otherwise would be an irrational act on the part of the “offending” householder!

Comparison of rangeland management grazing practices under traditional systems Vs modern practice.

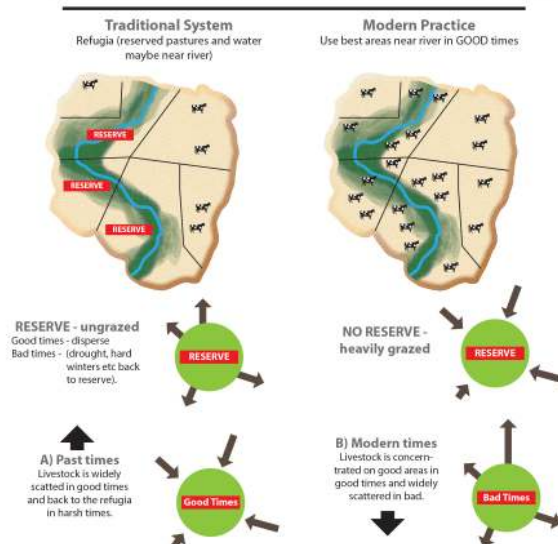


Fig. 5. A model to explain the shift in grazing management on common resource grazing lands (past and present)

FIVE HUMAN-RELATED CAUSES THAT HAVE ACCELERATED SOIL LOSS IN THE GKMA

Accelerated soil loss and land abandonment in the rural karst mountainous areas of Guangxi is widely believed to be a consequence of road building activities that cause soil erosion, housing construction, steep slope cultivation, tourism development, and animal trampling from goats, sheep and cattle. But geomorphic features such as degree of slope, elevation, aspect also bring about differences in the distribution of settlements. Settlements are places where humans gather and live. The fragmentation of land surface in karstic landscapes leads to considerable differences in the form of settlements, and there is a spatial coupling relationship between settlements and the quantity and quality of cultivated land. Settlements with different degrees of distribution are accompanied by spatial differences in cultivated land resources, which lead to differences in the sufficiency of cultivated land resources.

According to Zhang et al., (in press) cultivated land is closely related to life style and livelihood. However, in the past, the coupling effect between cultivated land and the degree of settlement was seldom considered, and the spatial distribution and influencing factors of cultivated land in complex karstic areas were also insufficiently understood. Cultivated land is a valuable

resource for ensuring food security and the high-quality development of the economy in these karstic landscapes, especially on flatland or stable terrace lands. Figs 2c and Fig 3). Human factors greatly influence the utilization of cultivatable land, and the influence of human factors on the temporal and spatial evolution of cultivated land is proportional to the degree of settlement and intensity of land use. The highly variable landscape, so typical of karstic areas, makes cultivated land an important resource that is under pressure to be transformed into other land uses as part of Guangxi's social and economic development. Simultaneously, its changes reflect the evolutionary characteristics of the human-land relationship, as well as presenting a snapshot of the current situation and problems of agriculture in the context of social development (Feng, Squires & Wu, 2021; Feng & Squires 2018). According to Ze and Song (2020), environmental factors have generally exerted a more significant effect on land abandonment within the GKMA than socioeconomic variables. There is a clear need to follow up this observation.

COASTAL REGIONS ON THE BEI BU GULF OF THE GZAR HAVE EXPERIENCED RAPID DEVELOPMENT AND ARABLE LAND LOSS

Rapid development and huge investments in transport infrastructure, port development, nuclear power stations, modernized SMART manufacturing, shipbuilding, SMART agriculture and marine aquaculture have come to coastal cities like Qinzhou and Fangchengeng. Their associated peri-urban areas are a magnet for labor and capital inflows (Feng & Squires, 2018; Feng, Squires & Wu, 2021). Loss of arable land has accelerated as peri-urban areas and construction land has been given priority (Feng & Squires, 2021a, 2021b, Wadduwage, 2018). At the same time, some depopulation has occurred in the hinterland over the past 20 years and land abandonment is a consequence of the urbanization policy being pursued by the government. We know, from the valuable work of our colleagues (Hu et al., 2018) that there was a modest loss of arable land across the GZAR (Fig 6a and b). Part of this was in response to retirement of cropping land and the planting of trees on the site (often slopeland) under the 'Grain for Green' national initiative (Rozelle, 2005). The biomass has increased in many areas as trees, shrubs and grasses grow (Zhang, Wang, Yue et al., 2010) but the contribution to livelihoods of this marginal cropping land was partly replaced by government subsidies.

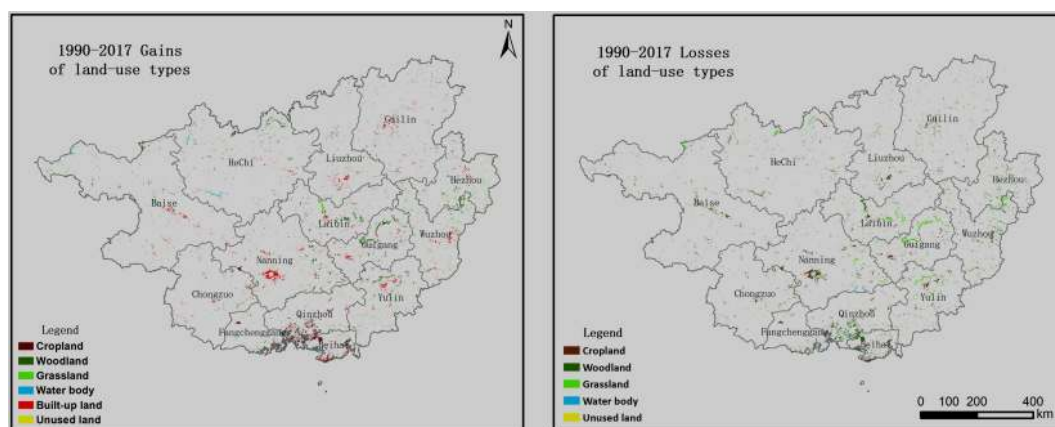


Fig 6 The spatial pattern of land-use change in Guangxi (1990–2017), including gains (left) and losses (right) for specific land-use types. (After Hu et al., 2018, used with permission)

SUMMARY AND CONCLUSIONS

The whole question of land use change and in particular concerns about loss of valuable arable land has generated a number of approaches. Some have relied on advanced satellite-based data capture and most have used sophisticated software to come up with useable quantitative data. Others have relied on field visits with semi-structured interviews (like PRA⁵) to assess, from the land users themselves, their observations of what changes have occurred and also their perceptions of what the future will hold. Government policies are changing – especially the approach to poverty alleviation and to re-location and re-settlement. This has changed peoples' attitude. The relaxation of the hukou⁶, the “pull” and “push” factors that make it easier to leave their ancestral homes and send remittances to support their ‘left behind’ family (typically grandparents and their grandchildren). Researchers have identified “hollowed out” villages (Ye, 2018) where able-bodied people leave to seek work (or study/training) in the county towns, the capital (Nanning) or coastal cities like Qinzhou or Fangchenggang. The impacts of this need more detailed study.

There is a clear need to follow up the observation made by Ze & Song (2020) that environmental factors have generally exerted a more significant effect on land abandonment within the GKMA than socioeconomic variables.

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⁵ Participatory Rapid Appraisal is well tried technique in rural development studies

⁶ China's hukou system was introduced in 1958 as a modern means of population registration. In its current version, the Hukou fulfills three main functions: the control of internal migration, the management of social protection, and the preservation of social stability. Recent reforms allow conversion of rural residence permits to urban locales.

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