

## **Land-Use Planning and Remote Sensing as Instruments for Erosion Control in the Loess Plateau of Shaanxi Province, P.R. of China**

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**Abstract:** In the context of a bi-national research project, financed by the German Federal Ministry of Education and Research (BMBF), two chairs of Munich's Technical University are engaged in an intensive research work in close co-operation with the Northwest Sci-Tech University of Agriculture and Forestry (NSTUAF) in Yangling, Shaanxi, investigating the problem of soil erosion in the north-western province of Shaanxi, P.R. of China.

The scientific approach bases on the use of land-use planning techniques and geobotanical investigations in the field, as well as on the interpretation of remote sensing products like satellite images and multi-temporal satellite data. Whereas these parts are granted by the German project partners, the Chair of Land-Use Planning and Nature Conservation and the Chair of Geobotany from Munich Technical University, the Chinese partner contributes by conducting master studies with emphasis on various aspects of the project's objectives and by establishing the necessary logistical efforts.

Summarizing the facts, it has to be stated, that sustainable progress in the fight against erosion on the investigated areas of the Loess Plateau will decisively depend on the success of anti-erosion measures. Informations concerning an adapted land-use are furthermore necessary to increase the acceptance of sylvo-pastoral systems in combination with alternative agricultural measures within the rural population, that could offer the farmers at the same time sufficient arable land, forests and grazing grounds to assure their survival.

**Keywords:** erosion control, loess plateau, land-use planning, geobotany, remote Sensing

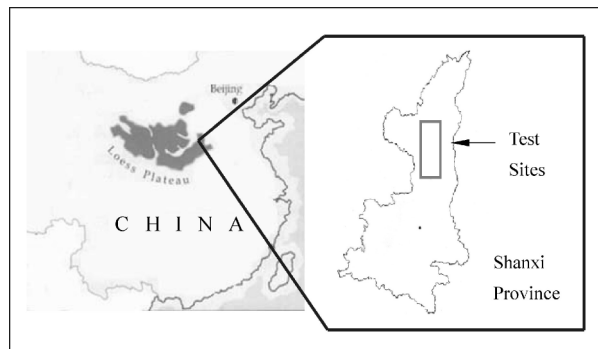
### **1 Participants of the current project**

In the context of the project "Erosion control in the province Shaanxi of the P.R. of China", financed by the German Ministry of Education and Research (BMBF), an inter-disciplinary, Sino-German consortium of scientific institutions performs a variety of investigations concerning the erosion in Shaanxi's loess plateau. On this behalf, two institutions of Munich's Technical University, the Chair of Land-use Planning and Nature Conservation and the Institute of Geobotany are engaged in an intensive research work in close co-operation with the Northwest Sci-Tech University of Agriculture and Forestry (NSTUAF) in Yangling, Shaanxi.

### **2 General problem**

The loess plateau of north-western China covers about 580.000 km<sup>2</sup> of the provinces Shaanxi, Shanxi, Inner Mongolia, Ningxia, Gansu, Henan and Quinghai.

This area, mainly deforested for thousands of years, represents one of the economically weakest parts of China. The annual erosion of the soil reached a level of 51 metric tons/ha in 1991, a rate that corresponds to the removal of 1 cm soil from the region every year (LUK, 1991). The area affected by this phenomenon is estimated to a total amount of 43 mio ha or 80 percent of the loess plateau (cf. to SIDER, 1999).



**Fig.1** Location of the loess plateau and the test areas in the province Shanxi China

These dramatic effects pose severe ecologic and economic problems far beyond the local scale by also influencing key environmental indicators like the sediment deposit rate in the Yellow River or the runoff and loss of organic matter and macro-nutrients from the loess plateau.

### 3 Objectives of the project

Accordingly, the objectives of the project have to be subdivided into objectives on a regional scale and objectives a local scale.

#### Objectives on a regional scale:

- Classification of the actual land-use.
- Determination of the loss of usable surfaces per interval.
- Mapping of erosion perils for the identification of landscape units with a top priority regarding the protection against erosion by agro-forestry or soil-bioengineering.

#### Objectives on a local scale:

- Detailed mapping of the actual land-use.
- Gathering knowledge concerning the remaining forest vegetation and the spontaneous secondary vegetation.
- Gathering knowledge concerning the spontaneous development of vegetation after the suspension of grazing.
- Improvement of the detail knowledge about native trees and shrubs against the background of their contribution to the economic situation of the local inhabitants.
- Review and further development of soil-bioengineering methods for the fight against erosion in combination with adapted land-use systems.

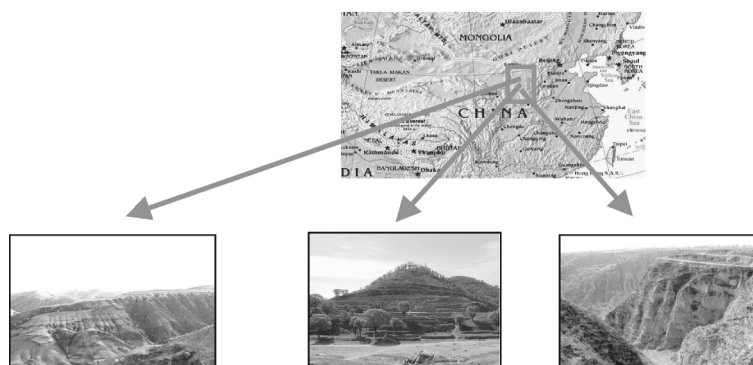
### 4 Investigation areas, climate and geography

The great accumulations of wind-derived silts that create most of the loess plateau are not uniformly distributed. The greatest extents of the plateau loess are found within basins, most of which are of tectonic origin (cf. Derbyshire *et al.*, 1999). Dissection of these thick basin accumulations is locally severe, an effect that results in steep valley-side slopes.

In China, the **surface form** of the loess plateau is traditionally characterized by the use of the terms “yuan” (flat plateau landform), “liang” (elongate ridge landform) and “mao” (hemispherical hill landform). The scientific view on the origins of these forms vary from tectonics to sequential fluvial erosion (cf. Liu *et al.*, 1958; Liu and Chang, 1964; Wang and Zhang, 1980). The **investigation areas** have been chosen in a way to ascertain that each of these landforms will be covered by the investigation.

The **actual climate** on the loess plateau is dominated by the Asiatic monsoon, with marked seasonal shifts in dominant winds being characteristic. In winter and spring, strong temperature contrasts between the cold Eurasian continent and the relatively warm surrounding ocean waters give rise to the Mongolian-Siberian high and the Aleutian low pressure systems. These maintain a dominant flow across North China

of cold and dry air from the north and west, known as the winter monsoon (Zhang and Lin, 1992; cf. also to Derbyshire, 1999).



**Fig.2** The landscape types of the investigation areas (left to right): “Liang” near Yan’An, hemi-spherical hill (“Mao”) north of Yan’An, agricultural used plateau near Yangquan

In summer, low atmospheric pressures over southern Asia and high pressure cells over the Indian Ocean and the subtropical west Pacific ocean induce a strong influx of warm, oceanic air as south-westerlies from the Indian Ocean-Bay of Bengal and south-easterlies from the South China Sea (the south and east Asian summer monsoons).

It is however the dry winter winds blowing dust from source areas in the deserts and mountains of the north and west of China that account for much of the deposition of this aeolian silt as loess on the loess plateau. The dominance of north-westerly air-flows in winter impose a strong winter temperature anomaly across China, a tendency that is enhanced by the extensive and very high Tibetan Plateau.

Summarizing, the mean climate values for the test sites in Shanxi can be stated with 300 to 600 mm annual precipitation (decreasing from the South to the North), mean annual temperature 10.5°C at an altitude between 400 (plain around Xi’An) to 1,400 m NN (hills around Yan’An) (Walter *et al.*, 1975).

## 5 Scientific approach

The scientific approach for the present project based on four main investigation subjects:

- Investigations concerning the status quo of the vegetation, the impact of grazing on the vegetation and potential anti-erosion measures.
- Investigations concerning the potential natural vegetation on the test sites and socio-economic aspects.
- Investigation of the actual situation of land-use on the test-sites using remote sensing techniques and monitoring of the erosion progress on a small-scale area.
- Appraisal and evaluation of actual anti-erosion measures and proposition of additional measures in combination with agro-forestry and soil-bioengineering techniques.

Within this paper, the main emphasis will be laid on the investigations concerning the actual land-use and the fight against erosion.

## 6 Investigation of the actual situation of land-use on the test-sites using remote sensing techniques

In the context of this work package, remote sensing data of several levels of detail have been used:

- LANDSAT ETM 7-scenes of September, October and December 1999 as well as of June 2000
- SPOT panchromatic stereo scene of March 1998
- CORONA panchromatic stereo satellite images of 1968 and 1971

Because of administrative restrictions, aerial photographs couldn’t be interpreted within the present project. The reference for the conducted investigations represent four LANDSAT ETM 7 scenes. After intensive testing of their geographical correctness and their comparability, these scenes have been used as a geographic reference for all following analyses and as a basis for the supervised land-use classification.

Therefore, the information from the multi-spectral channels of the sensor (resolution: 30 m) have been merged with the panchromatic channel by the way of an IHS-transformation in order to achieve the maximum resolution of 15 m per pixel.

To increase the accuracy of the following classification, a digital elevation model (DEM) has been combined with the LANDSAT 7 layers. For the computation of this DEM, SPOT stereo-panchromatic data of 1998 have been used as a basis for a terrain model of 10 m accuracy. It is a peculiarity, that within the supervised classification, the total amount of reflection per pixel was not used as the main distinction criteria. It has been replaced by a pixel-wise multi-temporal combination of the reflection values of several channels for all available scenes. The necessary training areas for the supervised classification have been assessed during intensive field campaigns on the test sites. In the course of this, about 200 training areas have been delimited on colour composites of LANDSAT data, described in detail and photographed in the field.

Another aspect of the remote sensing activities within the project focuses on the trial to detect landscape changes because of erosion by remote sensing. In order to achieve a comparison of the actual situation with the landscape form of former times, CORONA panchromatic stereo pictures of 1968 and 1971 have been used. These high-resolution pictures from a former satellite-borne recording system have been recorded between 1964 to 1971 and offer a high resolution of about 2 m for a sufficiently vast area. By the means of geo-processing with the software package "ERDAS IMAGINE" in its latest version, DEMs and rectified (ortho)images have been produced in order to monitor the progress of the erosion by visual and mathematical comparison with DEMs computed out of SPOT data from 1998. The necessary geographical reference has therefore been taken out of the LANDSAT 7-scene from September 1999 and out of videos, taken during the field campaigns, that offer a detailed impression of the land-use of 2001.

## **7 Appraisal and evaluation of actual anti-erosion measures and proposition of additional measures with emphasis on agro-forestry and soil-bioengineering techniques**

For this work package, the land-use of three valleys, about 20 miles to the north of Yan'An has been thoroughly investigated.

Because of the lack of topographic maps it was necessary to take pictures from the opposite hills at first. Following this, the land-use classes have been delimited on the pictures. Afterwards, a multitude of parameters have been assessed for each delimited class during an intensive field-assessment, describing the form and the use of the landscape as well as the situation and the value of present anti-erosion measures. Within this step, strong emphasis has been laid upon the description of actual or potential hazards by erosion effects on the delimited classes. If appropriate, possible improvements have been proposed. This activity will be complemented by an according diploma thesis at the Chair of Land-use Planning and Nature Conservation that is under preparation at the moment.

## **8 Preliminary results**

### **● Results of the remote sensing approach**

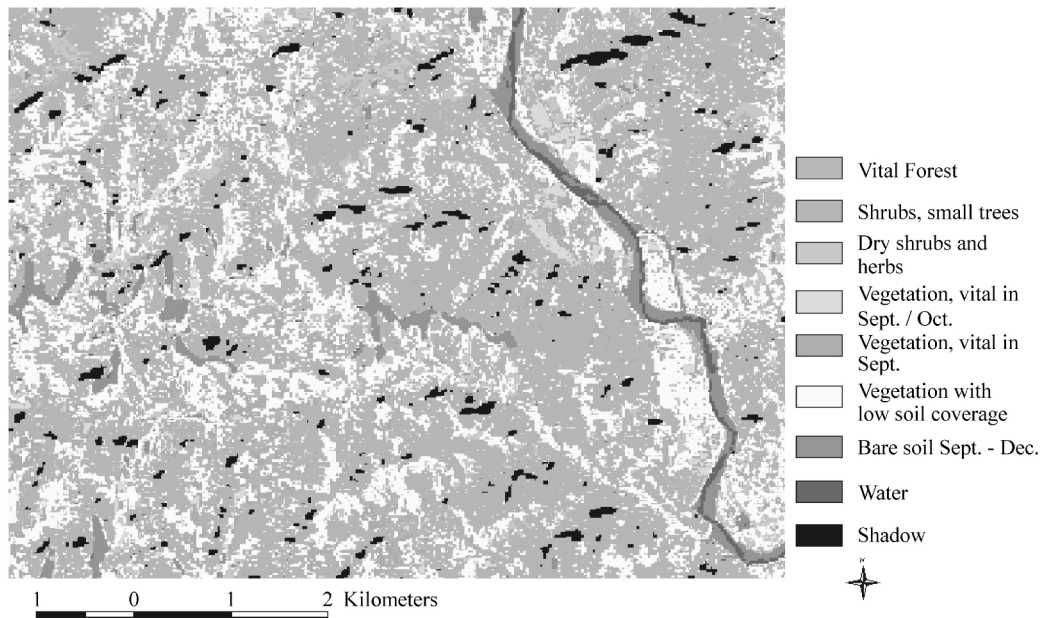
The most prominent result of the remote sensing work package marks the classification of the LANDSAT scenes for the three investigated areas. The following classes could be distinguished as shown in the following figure that demonstrates the classification result for the area north of Yan'An:

The classification proved, that especially in the northern investigation area near Yan'An, the distinction of the land-use classes is strictly influenced by the available humidity in the soil. The different reflection of each vegetation unit according to this phenomenon can easily be distinguished over the year by the use of multi-temporal LANDSAT 7 data. Moreover, the newly created terraces are clearly visible within the images (cf. to Figure 4).

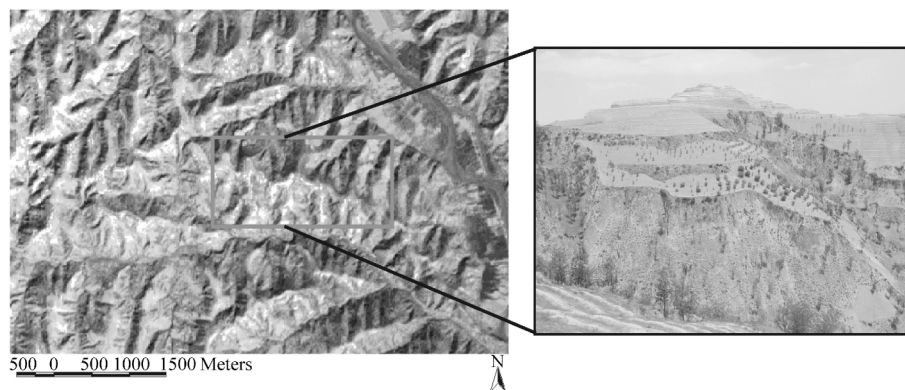
By changing their reflection in the process of initial use and cultivation, the actual status of these terraces can be detected. Thus, multi-temporal LANDSAT 7 data also offer a highly precise interpretation base of vast spectral potentials for the great-scale monitoring of vast areas.

The CORONA satellite images were essential as a basis for the creation of a digital elevation model and as a reference for comparison with the more recent data from the SPOT satellite. It has to be stated

however, that the direct comparison of SPOT stereo data with a resolution of 10 m per pixel with CORONA satellite images of a resolution of 2 m per pixel can only offer useful results for a low-detailed investigation and in order to detect vast hotspots of erosion in the landscape because of the relatively poor resolution of the SPOT data. For the detection of landscape changes on a small scale, the use of aerial photographs with an adequate resolution is essential and proved to remain the missing link within the project up to now.



**Fig.3** Result of the supervised classification of the multitemporal LANDSAT ETM 7 scenes of 1999 for the area north of Yan'An, Shaanxi



**Fig.4** Spectral reflection of freshly created terraces (white-reddish colour; left image) in LANDSAT ETM 7 data from 1999 compared to the real situation (right image)

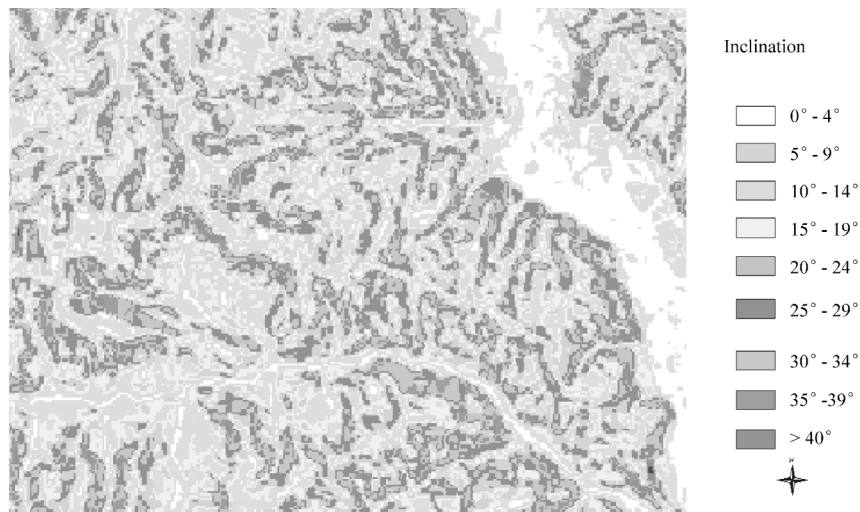
By the use of the combination of the DEMs with the LANDSAT data, thematic maps showing the inclination, the altitude and the declination of the investigated area have been produced (cf. to Figure 5).

The computing of ortho-rectified images helped to determine distances and thus substituted the lacking topographic maps.

#### **Results of the land-use assessment with emphasis on anti-erosion measures**

The land-use within the two test sites varies distinctively. On the hilly landscape of the area around Yan'An small-scale farming systems alternate with semi-arid shrubs and grass on steep slopes. The

landscape around Luochuan and Yangchuan, where flat agricultural plains alternate with steep, vast gullies is dominated by large-scale agricultural systems and succession vegetation on the slopes.



**Fig.5** Map of inclination for the area north of Yan'An

The problems originating from erosion are more severe in the northern part of the investigation area around Yan'An, where the farmers are in many cases obliged to cultivate small fields on steep slopes. Here, because of the lower precipitations, the cultivation of fruit trees retreats in favour of small-scale agriculture and the production of vegetables. Anti-erosion measures for the conservation of the endangered steep hills like terraces or fish-scale pits are frequent. One of the most important problem however constitutes the omni-present phenomenon of grazing there, that can be stated almost all over the whole investigated area. The rejuvenation and the growth of the secondary vegetation proves to be an efficient protection on those slopes that are not subject to grazing. The weight of the sheep and the cattle are sufficient to destroy the surface structure of the loess in a way to expose him protectionless to erosion.

The existing measures against erosion seem to be effective in principle, the following improvements can be proposed however:

- The slopes of the newly created terraces on top of the ridges have to be covered with vegetation quickly.
- The already existing fruit tree plantations on top of the terraces are only in some rare cases used for the cultivation of plants in a second layer. It has still to be investigated, on which conditions the seeding of soil-covering annual or perpetual plants beneath the trees can be recommended.
- In most cases, the existing fish-scale pits lack a vegetation cover. In order to avoid their deterioration, continuous maintenance is necessary.
- The drainage of the terraced slopes is in many cases not sufficiently organized. Adequate measures have to be carried out to avoid negative consequences from the runoff.
- The restriction of grazing should be enforced on the erosion-prone slopes. In order to assure the survival of cattle and goats for the needs of the population however, sylvo-pastoral systems are to be developed to offer the necessary amount of food by the creation of e.g. fodder hedges or common grazing grounds.
- The variety of cultivated fruit trees should be revised wherever possible to avoid the negative aspects of monoculture.
- The existing anti-erosion measures should be intensified. On small-scale sites already subject to erosion, even primitive counter-measures (for ex.: restoration of small gullies by simple check-dams, planting of soil-covering vegetation layer along the edge of small gullies etc.) could constitute effective counter-measures.

## 9 Outlook

The future development of the landscape within the investigated area will decisively depend on the extent of further improvement of existing anti-erosion measures and their conversion into practice by the means of soil-bioengineering and agro-forestry. Therefore, within the present project, erosion hotspots will be selected in accordance to the results of the comparison of CORONA and SPOT satellite images resp. data.

The results of the classification of the LANDSAT 7 data will offer an overview of the percentage of surfaces endangered by erosion in the investigated areas.

Summarizing these facts, it has to be stated however, that sustainable progress in the fight against erosion on the investigated areas of the Loess Plateau will decisively depend on the success of anti-erosion measures. Informations concerning an adapted land-use are furthermore necessary to increase the acceptance of sylvo-pastoral systems in combination with alternative agricultural measures within the rural population, that could offer the farmers at the same time sufficient arable land, forests and grazing grounds to assure their survival.

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