THE RESEARCH OF REMOTE SENSING APPLICATION ON THE LOESS PLATEAU

黄土高原遥感专题研究论文集

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内 容 简 介

本文集为"七·五"国家科技攻关项目"黄土高原遥感专题研究"的科研成果总结。其内容包括图象图形的计算机和光学处理；黄土高原的数字高程模型的建立及其应用；各种遥感信息源在黄土高原资源调查方面的适用性评价及其应用方法论；地物光谱分析及生物量和土地承载力遥感估测；遥感应用于土壤侵蚀机制研究；土壤侵蚀遥感定量分析及制图；计算机自动制图及其地理信息系统等。

本文集可供遥感应用、信息系统、图象图形处理、农业、林业、水土保持等方面的科研工作者和有关高等院校师生参考。

前　言

近年来，随着航天和航空遥感技术的发展，遥感技术在资源调查和工农业生产方面得到了越来越广泛的应用。

黄土高原地形破碎，千沟万壑，土壤侵蚀严重。在这样一种特殊的地域内，研究如何发挥遥感技术的优势；探讨各种遥感资料应用于黄土高原资源调查方面的适用性、工作方法和应用潜力，为遥感技术应用于黄土高原大规模资源调查提供依据。这是“七·五”国家攻关项目“黄土高原遥感专题研究”的主题目标。

整个研究工作从1986年论证开始，经过不到五年的艰苦努力，各子专题和有关单位协同攻关，无论是在理论基础探讨上，还是在应用技术方法上，都获得了具有实际意义的先进成果，圆满地完成了任务，达到了预期目的。而且，有些技术指标还超出了合同攻关目标。

为了总结这次研究成果，开展遥感技术交流，我们将此次研究中所取得的成果汇编成《黄土高原遥感专题研究论文集》。本文集收录88篇论文，打破了子专题序号而按内容排列。其内容包括图象图形的计算机及光学处理；黄土高原的数字高程模型的建立及其应用；各种遥感信息源在黄土高原资源调查方面的适用性评价及其应用方法论；地物光谱分析及生物量估测、土地承载力研究；遥感在土壤侵蚀机制、侵蚀定量和动态预测研究方面的应用；土壤侵蚀遥感制图方法论；计算机自动制图及其地理信息系统等。

本项目由中国科学院资源环境局主持。以北京农业大学全国农业遥感应用及培训中心、中国科学院自然资源综合考察委员会和北京师范大学地理系为主承担了这一专题研究任务；参加单位还有武汉测绘科技大学、西安交通大学、中国科学院遥感研究所、地理研究所、陕西农业科学院土肥研究所、黄土高原治理研究所、国家测绘局测绘科学研究所、水利部天津勘测设计院、黄河水利委员会等。参加这一研究工作的主要科技人员达54名之多。本文集是集体智慧与辛勤劳动的结晶。

由于本文集编辑出版时间局促，缺点和错误在所难免，希望读者予以批评指正。

编　者

1990年8月于北京

序　言

黄土高原是我国最严重的土壤侵蚀区域之一。土壤侵蚀不仅严重地影响本区工农业生产的发展和人民生活，而且也严重地影响了黄河下游的防洪、灌溉和水电工程。建国以来，我国政府曾多次连续地对该区进行大型综合调查研究。但是由于过去技术条件的限制，对该区的土地资源情况并不十分清楚。例如：侵蚀强度和侵蚀面积有多大？在侵蚀类型方面是以面蚀为主，还是以沟蚀为主？重力侵蚀的规律及其在产沙量中的权重又如何？已治理的面积，特别是水平梯田的面积究竟有多大？分布在什么地区？最近几年黄河对下游的输沙量减少了，究竟是由于大气降水减少，还是由于治理取得了效益？……，等等。为此，国家"七·五"科技攻关计划中，设置专项，希望利用遥感技术迅速解决这些问题。但是，黄土高原地区地形切割破碎，具有大量宽度小于5米和10米的切沟，以及宽度小于5米的梯田和面积小于0.3公顷的人工草地与林地；这些都低于第二代陆地卫星影象——TM和SPOT等影象的地面分辨率。而大面积的彩红外航空摄影的价格又比较昂贵。所以，在遥感技术的应用方面难度很大，其中不少关键技术问题亟待解决。因此，在进行黄土高原区域开发研究的同时，在遥感项目中又特别安排了"黄土高原遥感专题研究"。

该项目进行虽不到五年，但在有关单位及科技人员的共同努力下，通过大量的野外观测、制图和室内计算机处理、模拟等，取得了一批可喜的成果。例如：黄土高原大比例尺专业系列成图中遥感技术的应用；不同比例尺专业制图的遥感信息源的选择；土壤侵蚀定量遥感分析的系列实验；地形数字模型(DEM)在黄土高原土壤侵蚀中的初步应用；土壤侵蚀信息系统的初步研究；黄土高原土地人口承载潜力分析等等。这些研究成果不仅在方法上有所创新；同时，所获取的数据及其有关结论也很有应用价值，为今后遥感技术应用于土壤侵蚀打下了良好的基础。

更为可贵的是，通过这一协同攻关项目，培养了一批年轻有为的遥感技术应用研究的科技人才，并具有团结协作知难而进的科研作风。

这本论文集基本上反映了该课题的攻关内容和他们辛勤劳动的成果。为便于学术交流，编辑出版了这本论文集。但无论从时间方面，还是从空间方面来说，他们的实践终究有限。希望广大同行及读者阅后提出宝贵意见，以促进遥感技术应用与土地资源调查等学科的发展，为黄土高原的区域开发，为我国的社会主义建设事业更好地服务。

陈述彭

1990年8月21日于北京

INTRODUCTION

Remote sensing technology is becoming an important method for the studies on resources and enviroment, as it has advanced fast. Comprehensive application of multiple remote sensing information sources have come to an integrate technology system of remote sensing. This technology system includs image processing, information extracting, serially mapping, expert systems and GIS, mainly. The Loess Plateau, well known for its deep deposit and wide distribution of Loess is located between 103-112E and 34-38N in the Northwest China. For a long time, severe erosion not only has produced a great impact to agricultural in this area, but also silted up the reservoires and riverbeds in the lower reaches, so it has been becoming the most important cause seriously damaging the ecological system of the Loess Plateau and the near areas.

This monographic study of remote sensing application on the Loess Plateau is a comprehensive research that aims at soil erosion control, land use and management, and reasonable exploitation of natural resources. It's one of the National Research Projects taken on during the 7th-five-year plan period. The main trials were carried out in Mizhi County and Ansai County, Shanxi Province.

1. Image Processing

In this study, a great many experiments in image processing including combining bands, extracting principle component and image enhancement technology have been carried out. The edge enhancement has the best result among the image enhancement methods. Overlapping experiments of TM, SPOT and color infrared aerial photo, as well as experiments of scene matching have also been carried out in the study.

The specialized classifications, especially supervised and unsupervised classification were proved to be the most active realm. A program being able to compare the same class on different images was developed. Two sets of automatic mapping softwares were also exploited which can convert the data in grid form to vector form. The study also tried to find a practical method for automatic mapping by the computer.

2. DEM foundation

It's the basis of the GIS to produce DEM with infrared aerial photoes rapidly and automatically. Two methods were adopted, Analytical Method and Digitization Method. The software package of Analytical Method has been written. Apart from the elevation sampling along the coutour, the digital elevation model contains such information as structural lines, geomorphic feature lines, etc, therefore the model is more suitable to the hilly-gully region of the Loess Plateau. The software of auto-

matic mapping system written by C computer language adopt the algorithm of image matching based on the feature linking medol to improve the locating precision is suitable for image processing. The software of the SODAMS has been transfered to PCMX2 macrocomputer. Vertical project color infrared image and vertical project black-white image with contour lines were produced in this study.

3. Information source evaluation for application of remote sensing on soil erosion mapping and land use survey

Four kinds of information source (TM, SPOT, color infrared aerial photo and multitemporal black-white aerial photo) were evaluated by land use mapping and soil erosion mapping. The results show that TM and SPOT are suitable for soil erosion mapping at the scale of 1:100,000 and land use mapping at the second grade of the classification system, but not for soil erosion mapping at the scale of 1:50,000 and land use mapping at the third grade of the system, since both TM and SPOT cannot identify the terrace and small gullies in the hilly-gully Loess region. Each information source is evaluated comprehensively with mapping precision, economic benefit and classification accuracy. The methodology as well as a program was developed for natural resources investigation on the Loess Plateau using remote sensing information. The spectral resolution and space resolution of different information source were also researched.

4. Quantitative analysis of the soil erosion on the Loess Plateau using remote sensing technology

After analysis of the factors affecting soil erosion from remote sensing image and the data measured on ground, the erosion factors were quantified as well as matched to the polygons of the map, and modified further by the soil erosion quantity from the observed small watershed. The soil erosion type on the Loess Plateau is more complicated relatively. There are rillinterrill erosion, gully erosion and gravity erosion, each of which occurring regularly.

According to the features of landform and soil erosion, the total amount of soil erosion from a watershed(Y) consists of the amount of rill-interrill erosion above the Mao-Bian line(A) and the amount of gravity erosion below the Mao-Bian line(G).

(1) The amount of rill-interrill erosion can be calculated by the USLE equation. The USLE equation modified by the data from small runoff-erosion plots at six different angle founded by the Shanxi Loess Institute is that,

$$A = 1.244 + 0.240\,RKLSCP \qquad (r = 0.97)$$

where R is the rainfall factor,

K is the soil erodibility factor,

S is the slope gradient factor,

L is the slope length factor,

C is the cropping management factor,

P is the erosion control practice factor,

and 1.244 and 0.240 are modification coefficients.

(2) Sediment-Delivery Ratio(SDR), Only a part of the total rill-interrill erosion above the Mao-Bian line is carried out of the watershed by runoff because the other part is hold back, so the ratio of the carrying capability of runoff and the amount of rill-interrill erosion is the SDR on the slope field. It can be calculated by Meyer's erosion capability model and Kirkby's transport capability model, the main factors affecting the SDR are the soil erodibility factor(K), slope(S), comprehensive factor of crop management(P), root depth (RD) and relevent rainfall parameters.

(3) Erosion modlus of small watershed(Y): On the one hand, erosion modlus was measured practically (including semi-fixed position measurement of silt arresters of 21 small watersheds and stereo measurement with aerial photo of 170 silt arresters); on the other hand, it could be calculated by analysis of the erosion factors and simulating according to the practical data. The equation is that:

$$Y = R[0.306P^{-0.859}X^{-0.294}(0.062)^{D}(1.052)^{S}(0.985)^{L}(0.921)^{F}]$$

R——runoff modlus

P——% of vegetation cover and cured land area

D——cultivated slope land (%)

L——average slope length (m)

S——average slope gradient of the watershed (%)

X——circularity ratio of the watershed

F——content of 0.1-2.0mm fine sands (%)

Except the circularity ratio of the small watershed, the other factors can be related to the relevent parameters of the USLE. Therefore, the amount of the gully-gravity erosion below the Mao-Bian line is $G = Y \perp A \times SDR$.

To verify the above erosion models, we mapped the soil erosion with colour infrared aerial photo in Quanjiagou watershed in Mizhi county which has been measured serially since 1980. The map has 39 polygons with an area of 5.19km^2. According to the above technological procedure, the total erosion was calculated out and compared with the practical data, the relative error is 16.5%. This prove that the models was generally satisfying. All this form a theoretical and firat-step practical foundation on quantitatively mapping soil erosion on the Loess Plateau using remote sensing technology.

5. Study on comprehensive survey of land resources on remote sensing and land population supporting capacity

The purpose of the monograph was to supply a model to forecast about the dy-

namic state of the resources, the environment, the economy, the population and the society of Mizhi County and to put forward a proposal for making a strategic decision after mapping land type, evaluating land resources and analysing land potential production capacity using a lot of data including infrared aerial photo which was the main remote sensing information source.

The monograph had achieved the comprehensive study and mapping with remote sensing of land type, land use, land limitation choice and rating, land evaluation, the calculation of the potential product capacity of the main crops on nonirrigated farmland, and the system dynamic model analysis about potential population supporting capacity. Therefore, it achieved a seriation study; the comprehensive study of land type with remote sensing→ land resources evaluation→ land information system→ the analysis of land potential population supporting capacity and coordinated development of the resources, the environment, the population, the economy and the society.

In the study, the relationships of land, food and population in Mizhi County in the past 35 years had been summarized from a great of data. It has been indicated that the average living standard of people in Mizhi County would be only enough to eat and wear in a very long period unless developing the production and controlling the population be done very effectively since the average density of the population in Mizhi County has been 150 persons/km^2, especially, it had excessed 246 persons/km^2 in the river basin area.

In land evaluation, the ways of FAO's Land Suitability Evaluation and USDA's Land Capability Classification were adopted to achieve a conversions between these two ways and establish a land information system including a lot of graphic databases and relational databases supported by ARC/INFO by using a lot of features data.

6. Results of other monographic studies on remote sensing application

(1) Study on the stability of Loess gully, gravity erosion and undersurface erosion; The ground truth and the developing stages of thirteen sample gullies have been interpreted from the infrared aerial photoes. We could obtain distinct image marks and geometric parameters of the gully.

(2) Analysis of the relationship between the storm runoff and land cover by remote sensing; A quantitative model of producing runoff on the Loess Plateau has been established after analysing the relationship of the factors of topography, soil and vegetation cover which can be obtained from remote sensing information and the storm features (short period, strong intensity, small area and the uneven distribution in space and time). It's pointed out that the phenomenal is existed everywhere of producing runoff after permeating the ground. The conditions of producing flood are limited, and the decrease parameter in a watershed is determined.

(3) Measurement of agricultural object spectrum, spectral feature research and monitoring biomass; The reflect spectrum of agricultural object was measured in seven experimental fields in Mizhi County,and 17 soil samples were analysed in lab. The conclusions were drawn up from the data in different bands that there is little difference in the spectrum of bear soil in different degree of erosion because the soil organic material is low and parent material of soil is homogeneous.So it is difficulty to determined the erosion degree by reflect ratio; and little vegetation cover can cause a significant defference in reflect spectrum.

A per unit biomass yield model which is suitable for Mizhi County has been set up by analysing three year's data of spectrum of 36 samples from the 7 experimental plots.

CONCLUSIONS

Soil erosion is a natural process consists of detachment, transportation and deposit on the earth surface. It's casuse by numerous factors in geography,geology and the mankind activities.Remote sensing technology including space remote sensing and aerial remote sensing has a great advantage in the study on soil erosion and land resources. With the aid of GIS and ground monitor stations, a comprehensive technology network (including serially quantitatively mapping, dynamically monitoring and predicting flood and sediment with remote sensing) has been set up, which is important to regional development of the Loess Plateau.The 7th-five-year National Research Projects' monographic study on remote sensing application on the Loess Plateau has made a encouraging progress on all these above.

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黄土高原遥感专题研究技术总报告

专题总体组

黄土高原是我国土壤侵蚀最为严重的地区，严重地影响了当地的工农业生产的发展、经济建设和环境生态，进而也影响了黄河的中下游地区。同时，该区又是我国的革命老根据地之一，为我国人民的解放事业作出了卓越的贡献。所以，解放后党和政府对这一地区曾组织过多方面的、大型的综合调查和基点研究，可是对该区土壤侵蚀的全貌并不十分深入了解，因而对水土保持的决策也曾有不同的专业理解。例如：黄土高原的侵蚀究竟是以面侵为主还是以沟蚀为主？重力侵蚀的滑坡、滑塌、陷穴又占多大比重？这些现代侵蚀与新构造运动又有什么关系？因此，黄土高原的水土保持究竟是以“治坡”为主，还是以“治沟”为主？其中工程措施与生物措施之间的关系又如何？近年来以小流域为治理单元已产生了明显效果，而且近几年黄河的总输沙量是明显减少了，这究竟是由于治理产生了效果，还是由于近几年的降水量减少而使输沙量下降的呢？……总之，在有关科学界及领导决策中都存在着一联串的问题，而且众说纷纭，而无完整的科学实据。

问题的另一方面是遥感技术的发展。例如：在航天遥感方面，TM、SPOT 等第二代陆地卫星，具有多光谱、多时象与高分辨率的遥感信息源在解决黄土高原这种地形破碎、土壤侵蚀严重地区的资源调查与监测方面能起多大作用？具体的科学可行性与经济效益又如何？此外，近代迅速发展的彩红外高空摄影在解决上述难题方面又有多大优势？如何在现代遥感技术的支持下使我国的土壤侵蚀研究技术逐步现代化？

以上就是“七·五”科研攻关计划中“黄土高原遥感专题研究”课题成立的依据和背景。

一、“黄土高原遥感专题研究”课题的总体构思

在以上背景的基础上，经过课题总体组的多次讨论，并参照各参加单位的原有基础，形成了 10 个四级子专题，具体分述如下：

（一）各子专题的设立

1. *实用化遥感图象按地形图分幅、机助分类与自动化制图软件研究*

它是研究黄土高原地区卫星影象的处理技术与自动制图技术，其中包括：

（1）影象的纠正和按地形图分幅镶嵌。

（2）影象增强处理，满足黄土高原土壤侵蚀和土地利用分类的要求。

（3）计算机自动制图软件的研制。

2. *为黄土高原提供正射影象图与数字高程模型的典型研究*

它是研究黄土高原地区的数字高程模型（DEM）及其应用问题，其中包括：

（1）研究和提供试验区（米脂县）1∶5 万的彩红外正射影象图，为各专业提供制图底图。

（2）研究试验区高程数字模型及有关应用软件，为 GIS 的建立和土壤侵蚀研究服务。

3. 航空象片、TM和SPOT等遥感数据在土地利用现状和土壤侵蚀调查中的应用方法和评价报告

它主要是研究黄土高原两个试区（米脂与神木两县）中的系列成图技术和有关的信息源评价问题，其中包括：

（1）黄土高原区1:5万的系列成图技术，即土壤侵蚀图、土地利用现状图、森林与草场资源图等专业系列图中要求具有一些统一的地物边界，如峁边线和坡脚线。它既保证专业系列图上的理论相关，又能便于专业信息的迭加应用。

（2）在上述专业成图中，对TM、SPOT和彩红外航片等遥感信息源的应用进行综合评价，其中包括不同制图比例尺的应用。因为黄土高原具有地形破碎、田块较小等一系列特殊性。

4. 土壤侵蚀的遥感定量化分析方法研究

它主要是研究土壤侵蚀量——土壤侵蚀模数的遥感影象的因子分析与侵蚀量匹配的理论基础，因此，它必须：

（1）对黄土高原区的不同土壤侵蚀类型，以小流域为单位进行定量和半定量的系统观测，取得实地数据，对已有的土壤侵蚀模式及有关参数进行区域修正或组建有关模型。

（2）对已取得的观测数据的土壤侵蚀模型及有关参数进行遥感影象的因子分析、权数匹配和区域验正。

5. 土地结构与土地承载力的遥感分析和土地适宜性与限制性的总体评价

它主要是研究黄土高原区目前土地利用结构的优缺点、土地适宜性评价和人口承载潜力。因此，它要求：

（1）结合遥感影象，研究试验区（米脂县）现有的农、林、牧业等土地利用结构及其生产力。

（2）利用遥感影象绘制试验区的土地类型图，并进行土地适宜性评价，从理论计算其土地的生产潜力及其人口承载潜力，并提出区域开发方案。

6. 黄土沟谷稳定性计算和图象分析及预测动态变化趋势

它主要是研究黄土高原谷沟发育规律及其在遥感影象的表征，并结合区域的自然因素和人为活动因素等综合分析，对黄土高原沟谷的区域发展趋势进行预测，为水土保持的有关措施提供一些遥感-地学依据。

7. 黄土高原重力侵蚀与潜蚀的遥感分析

重力侵蚀与潜蚀，实际上是黄土沟谷谷坡发展及其稳定性的一个重要方面。在某些方面，它必须更侧重于地学研究，为遥感的影象分析打下基础。

8. 黄土区暴雨与下垫面关系的遥感分析，并提出径流预报模型

它主要是研究黄土高原区的暴雨、下垫面与洪水的关系，并结合遥感计算，提出小流域的暴雨径流模型，为土壤侵蚀服务。

9. 黄土高原区草场资源生物量的遥感监测与定量分析

它一方面是探求遥感信息在这一试验区（米脂）估算草场生物量的方法，另一方面也了解它和土壤侵蚀的关系。

10. 黄土高原区农业地物光谱特征研究及其应用基础研究

它主要研究黄土高原区的地物光谱特征，为遥感领域中的一项基础性研究；另一方面，也探讨用于生物量估测和土壤侵蚀监测的可能性。

（二）各子专题间的总体关系

上述10个子专题，它们既有区域性的应用性研究，也有一些基础性研究，它们之间的总体关系是比较明确的，具体可参考框图（图1）。为了简化起见，在框图中将不再用各子专题的具体名称，而是分别采用其序号。从框图可以看出：

（1）这十个子专题都是根据黄土高原地区的生产和地区性问题而提出的，以遥感技术和有关学科为主要手段而形成的一个有机总体。

（2）在这十个子专题研究中是以03、04、05三个子专题为中心，这是由当地的生产与研究课题的学科特性所决定的。

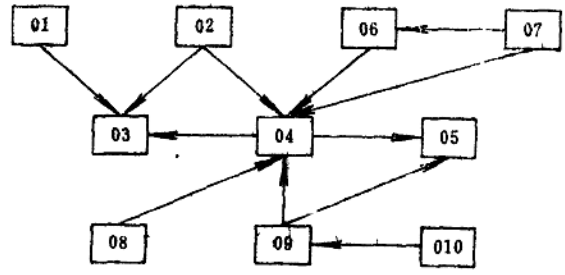

图1 各子专题间的总体关系框图

二、04课题研究中所取得的具体进展

课题组于1986年接受任务，1987年正式开展工作。各子专题在明确各自任务的基础上，同心协力，不仅按时、按项目协议完成了各自的任务，而且在项目的执行中，由于学科的发展和需要，有些子专题还自己增加了部分非协议内容，如土壤侵蚀信息系统即为一例。现分述如下：

（一）实用化遥感图象按地形图分幅、机助分类与自动化制图软件研究

主要参加单位有北农大遥感中心和中科院遥感所，此外国家测绘局研究所也进行了有关研究。具体研究工作内容和已取得的成果为：

1. 图象处理：包括一般性图象处理与影象加强，图象迭加和图象镶嵌技术等方面。

图象加强：其中有线性拉伸、比值增强和边缘增强等几个方面的研究，由于黄土高原地形破碎，以边缘增强效果较好。

图象迭加：将不同的遥感源的影象进行迭加，如SPOT与TM，彩红外航片与TM（局部）等，使地面分辨率和光谱分辨率的优势相结合而便于专业解译。

图象镶嵌：主要根据地形图分幅要求、将相邻象幅的光谱信息与空间信息进行调整、配准与复合。

2. 图象分类：其中包括监督分类与非监督分类。视软件的不同，这两种分类方法有各自的优点和缺点。为了比较各种分类方法的效果，发展了相同类别的比较程序（TV），即在土地利用分类中，利用不同影象系统地比较信息，能较快判断不同时象中各类别变动的情况。

3. 自动制图：由图象的光栅数据向矢量数据转换，分别研究了两套自动化绘图软件。

（二）为黄土高原提供正射影象图与数字高程模型的典型研究

主要参加单位有武汉测绘科技大学、西安交通大学，其它如中科院综考会，北农大遥感中心也进行了与遥感影象的光学处理有关的工作，具体的工作成果有：

1. 为了实现高速度、全自动地建立黄土高原的数字高程模型，武测在原有的“全数字化