

煤矿区复垦农田景观 演变及其控制研究

付梅臣 胡振琪 著

地质出版社

内 容 简 介

本文借鉴生态、采矿、农林、环境、土壤、土地管理等学科的有关理论与方法,采用实地调查和观测等研究手段,对平原煤矿区复垦农田景观格局与重建的理论、方法、施工工艺等进行了系统研究。选择华北地区采煤沉陷地、农场等农田景观为研究对象,阐述了一般农田景观的短期或定期零星农田、长期集中连片农田和配套集约化农田等的演变规律,揭示出采煤沉陷地复垦农田景观由平地转为积水、坡耕地、裂缝的演变规律和景观格局特征。按照可持续发展理念,提出复垦农田景观规划的设计原则、规划体系和内容与方法,阐明“3S”技术在复垦农田景观规划设计中的应用方法。设计了“条带复垦表土外移剥离法”、“梯田模式表土剥离法”等生态复垦(预复垦)表土剥离工艺,分析了土地平整工程费用和产权配置对复垦项目的影响。提出复垦农田景观的生产力、健康性和美学的评价方法,建立了小尺度采煤沉陷地复垦农田景观的质量评价体系及方法。最后,通过对兖州市兴隆庄镇采煤沉陷地复垦项目的质量评价,总结了土地复垦工程中存在的问题与复垦后的补救措施。

图书在版编目(CIP)数据

煤矿区复垦农田景观演变及其控制研究/付梅臣 胡振琪著.
北京:地质出版社,2005.7
ISBN 7-116-04506-6

I. 煤... II. 付... 胡... III. 煤矿-矿区-复土造田-
研究 IV. TD88

中国版本图书馆 CIP 数据核字(2005)第 073387 号

责任编辑:陈 磊
责任校对:田建茹
出版发行:地质出版社
社址邮编:北京海淀区学院路 31 号,100083
电 话:(010) 82324508(邮购部);(010) 82324565(编辑室)
网 址:<http://www.gph.com.cn>
电子邮箱:zbs@ gph.com.cn
传 真:(010) 82310759
印 刷:北京长宁印刷厂
开 本:787 mm × 1092 mm ¹/₁₆
印 张:8.5
字 数:200 千字
印 数:1—800 册
版 次:2005 年 7 月北京第一版·第一次印刷
定 价:22.00 元

ISBN 7-116-04506-6/F·203

(凡购买地质出版社的图书,如有缺页、倒页、脱页者,本社出版处负责调换)

作者简介

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序

煤炭资源开发,保障了我国国民经济的高速发展,为国家和人民创造了巨大的物质财富,同时也压占和损毁矿区水土资源,改变原有环境景观格局,严重者诱发地质灾害等,破坏并诱发一系列的社会和生态安全问题。

我国煤矿区地表及耕地损毁严重,使人地矛盾更加严重,同时也破坏了生态环境景观。目前,我国的土地复垦工作发展迅速,以矿区生态系统健康与环境安全为恢复重建目标的生态复垦逐渐受到重视。对城镇、郊区甚至农村景观形态的研究,近10年来也受到国际环境学界、社会学研究等的极大关注。

土地复垦是在社会生产力发展到一定阶段,人类与土地关系以及与生态环境关系陷于深刻危机的严峻时期,为了解决土地利用中的土地破坏及生态环境问题而派生出来的交叉学科。复垦农田景观生态重建是土地复垦中的重要研究领域之一,尤其小尺度的研究对具体土地复垦工程的应用价值较更大。所以,研究小尺度复垦农田演变规律及其控制,是非常有必要进行研究的,其研究结果必将对土地复垦有重要意义。

矿区复垦农田景观生态重建是一个涉及土地规划管理和生态环境等多学科的边缘交叉研究领域,对相关理论和方法的系统研究在我国尚处于起步阶段。作者借鉴一般农田景观演变规律和发展趋势,选取典型矿区复垦地为研究对象,采用实地调查和观测等研究手段,对矿区复垦农田景观生态重建开展了一系列的研究。研究工作在分析一般农田景观演变规律的基础上,结合矿区复垦实例铺展研究:从复垦农田景观格局演变规律和景观指数相互关系,到复垦农田景观重建模式的规划控制及控制模式与方法,再到复垦农田景观质量评价体系。在获取丰富翔实的数据的基础上,归纳总结出矿区复垦农田景观生态重建的规划、控制及评价的一般适用标准或体系,对于推动我国相关领域研究进展具有重要意义。

本书的核心优势在于将景观生态学的理念、理论、模型和方法同因为煤矿开采沉陷引起的地表变形及土地复垦、土地整治结合起来,使变形得到有效控制,景观格局系统优化。

该书内容丰富、结合实际,提出了自己的观点,对我国今后土地利用具有重要的参考意义。

中国工程院院士

韩德馨

2005年5月8日

前 言

我国是以煤炭为主要能源的国家,大规模的煤炭资源开发,导致了大量土地的破坏,并引发了一系列社会和生态安全问题。由于土地破坏的不可避免性,破坏原因及类型的多样性,破坏土地的量面广特征以及其影响的严重性和长远性,复垦农田生态重建正日益成为世界性的研究热点。本文综述了国内外复垦农田景观研究现状及其发展趋势,针对农田景观研究相对较少,对小尺度农田景观的研究,特别是小尺度复垦农田演变规律及其控制研究几乎空白等状况,试图在国内外生态恢复实践和已有研究成果的基础上,主要从景观生态学角度出发,借鉴生态、采矿、农林、环境、土壤等学科的有关理论与方法,以山东省兖州市兴隆庄采煤沉陷地、河北省中捷友谊农场农田、河北省安国市伍仁桥镇农田等为研究对象。同时结合国家自然科学基金项目(49401007)“开采沉陷对耕地的破坏机理及复垦对策研究”,通过实地调查和观测,较为详细地研究了复垦农田景观格局演变规律,建立了小尺度复垦农田景观质量评价体系和方法,提出了复垦农田景观重建工程调控模式与方法。主要研究内容及结论如下。

(1) 通过历史文献和华北较典型的两个旱作农业区域农田景观过程分析,揭示出一般农田景观格局演变规律。农田景观格局的形成有其历史、自然、人文等原因,比较复杂。农田景观格局是人类及其环境空间分布差异的表现,是由人为干扰形成的,其规模、形状、结构和质地各异,是各种复杂的自然和社会条件相互作用的结果。在农田建设的初级阶段,农田景观格局明显表现出对自然环境的适应性特征,随着人类生产技术的进步,农田景观格局更多地体现在人与自然的和谐。在这样的过程中,农田景观格局大致经历了短期或定期零星农田、长期集中连片农田、配套集约化农田和精准农业的发展历程,而农田景观格局的变化又能反映社会的发展和科学技术的进步。

通过中捷友谊农场不同时期的农田景观格局特征分析,验证了一般农田景观格局演变规律。同时揭示出农田景观指数特征如下:斑块密度(PD)、最大斑块指数(LPI)、斑块面积(AREA)、斑块周长(PERIM)与农田集约化水平呈负相关,农田集约化程度越高,斑块密度、面积、周长越小;边界密度(ED)与农田斑块规模与数量相关,当面积一定时,PD越高ED越大,PD一定时,斑块面积越大ED越小,而一定区域内,农田斑块面积增大时,PD相对降低,ED同时减少;斑块周长面积比(PARA)随着斑块面积的增大而减小,说明斑块面积越大,单位面积上的边界数量越少,相应地,斑块内部生境面积就越大;零散农田的景观形状指数(LSI)较大,形状不规则,但在人为干扰下,基本上较规则,斑块形状指数(SHAPE)接近1,即斑块形状呈方形或近似方形,显现出人工雕琢的迹象;平均分维度(FRAC)接近1,表明农田形状比较简单,接近规则方形;斑块周长面积比(PARA)在一定区域内应该有其合理的上限和规模利用的下限,其大小取决于当地自然条件、经济条件和文化背景,旱地高于水田。斑块面积(AREA)与斑块周长

(PERIM) 呈正相关, 与斑块周长面积比 (PARA) 呈负相关; 斑块形状指数 (SHAPE) 与分维度 (FRAC) 呈正相关。

(2) 通过兖州市兴隆庄煤矿区农田沉陷前后、复垦前后的景观格局特征分析, 揭示出采煤沉陷地复垦农田景观格局演变规律和景观指数间的相互关系。在井工开采干扰下, 农田景观过程及格局取决于采空区的形状、采厚、采深、煤层倾角、地表潜水位和顶板管理方法等, 积水、坡地、裂缝是开采后农田景观主要格局。

2003 年兖州市兴隆庄镇煤炭投产已经达 22 年, 在井工开采干扰下, 农田景观格局随着开采进度的增加, 地表逐渐沉陷, 由平坦农田转为坡耕地和积水, 并且随着开采进度增加范围逐渐扩大, 未沉陷的农田斑块形状规则, 边界整齐, 区域内廊道破损, 不能完全通畅。沉陷的农田主要演变为常年积水水面、季节性积水地、坡地等景观, 其中积水区域占 68.6%。未沉陷农田斑块平均面积为 4.03 hm^2 , 斑块形状指数平均为 1.17, 周长为 937 m, 斑块周长面积比平均为 326 m/hm^2 , 分维度为 1.06; 沉陷地斑块平均面积为 156.58 hm^2 , 周长为 6600 m, 斑块周长面积比平均为 42.96 m/hm^2 , 斑块形状指数平均为 1.30, 分维度为 1.04, 说明沉陷后的斑块形状近似方形, 地下煤层地势平缓, 地表沉陷形状大致与地下开采边界对应, 说明采矿对地面农田景观破坏性是巨大的。

随着开采沉陷范围的扩大, 斑块密度减少, 斑块面积和斑块周长增加, 农田集约化程度下降; 沉陷农田的景观形状指数较大, 形状不规则, 斑块形状指数仍然接近 1; 未沉陷农田与外界其他乡镇的廊道的连接度非常低, 廊道密度偏高, 连接度差, 农田利用率低, 农田和农田恢复资金投入少, 而且与机械化程度较高的农场相比, 斑块形状指数、分维度都与其有明显的差距, 存在农田景观滞后性。

(3) 通过对当前土地整理复垦工程调查和分析, 提出复垦农田景观重建工程调控模式与方法。煤矿区土地复垦方向主要是生态重建。近阶段土地复垦优先考虑恢复为耕地, 以生态农业为方向的复垦农田景观能够协调社会、经济、生态效益, 保障煤矿区社会经济持续发展。

复垦农田景观重建规划设计对象和内容不同于一般景观, 合理组织农田斑块、廊道的空间格局和基质重构工艺是其核心内容。“3S”技术的发展为农田景观规划设计提供了研究手段和技术支持, 促进了农田景观研究和农田景观规划设计的现代化。

复垦农田景观重建需要通过工程实施来实现, 使复垦土壤达到最优的生产力。按照复垦农田景观重建要求设计了“条带复垦表土外移剥离法”、“梯田模式表土剥离法”等生态复垦表土剥离工艺, 同时根据淹没后土壤质量低下, 复垦需要投资进行土壤改良等不良影响, 设计了生态预复垦的表土剥离工艺。

以河北和山东省土地整理复垦工程费用为例, 对工程费用结构进行了详细分析, 依据项目费用的敏感性, 其排序为土地平整工程、农田水利工程、田间道路工程和其他工程。为降低土地整理复垦费用, 提出了四项控制对策。

在对煤矿区沉陷地产权现状综合分析中, 阐述了当前沉陷地产权设置上存在的问题和原因, 并结合土地产权理论, 提出以补代征模式、产权分割与组合模式的产权配置思路。

(4) 按照土地可持续利用要求, 建立了复垦农田景观质量评价体系。复垦农田景观质量包括其生产能力、健康水平和美学价值, 考虑到复垦农田景观的当前状态及今后可能

的发展趋势，应以它对农田生产、农田环境健康和观光旅游功效作为判别质量的标准，建立小尺度采煤沉陷地复垦农田景观质量评价体系。指标体系主要包括景观生产力、景观健康水平和景观美学价值，利用内插中值法建立了五级质量评价标准。在对单一农田景观指标评价的基础上，采用因素加权求和法计算综合质量指标，对照质量评价标准得出复垦农田景观质量。

兖州市兴隆庄沉陷地复垦项目是该区域较典型的复垦农田景观生态重建实例，经过对其复垦农田土壤生产力水平、复垦农田设施配套水平、农田生物多样性、土壤环境质量、农田景观舒适度、农田景观文化价值等方面的评价，分析复垦农田景观生产力、健康水平和美学价值，评价结果表明该复垦农田景观生态重建是不理想的，存在一些不足之处。这也是目前土地开发整理复垦工程中普遍存在的现象，需要将规划设计、表土剥离、产权配置等环节与生态重建融合。同时，针对类似兴隆庄沉陷地复垦项目提出逐步调整农田景观格局、增施有机肥、合理配置植物、发挥产权配置功能和发展节水农业等补救措施。

Detailed Abstract

Coal is one of major energy resources in China. Large-scale exploitation of coal resources, has led to the destruction of a large amount of land, and has initiated a series of social problems and ecological safety. Owing to unavoidable nature of land destruction, varieties of its causes and types, characteristics of large-quantity and wide-range of land destruction, ponderance and long-term of its influence, this subject on the ecological reconstruction of reclaimed farmland is increasingly becoming the worldwide research hotspot. The research status and developing trends of reclamation farmland landscape at home and abroad is firstly summarized in the dissertation. Due to the fact that the research of farmland landscape is relatively little compared with other landscapes and the weakness of research on the small-scale farmland landscape, especially the research about the evolvement rule of small-scale reclamation farmland is almost blank. Based on ecology restoration practice and the research production at home and abroad, chiefly from the point of view of landscape ecology, and the author consulted the theories and methods such as ecology, mining, farming and forestry, environment and soil science. The author took the mining subsided land at Xinglongzhuang in Yanzhou City Shandong Province, the farmland of Zhongjie Friendship Farm Hebei Province, and the farmland of Wurenqiao at Anguo City Hebei Province as research objects. This dissertation combined with the natural science fund project of China (No. 49401007) namely "Impact of mining subsidence on farmland and its comprehensive reclamation technology". By means of the researches and observations on the spot, the evolvement rule of reclaimed farmland landscape pattern is studied deeply, and quality evaluating system and method of small scale reclaimed farmland landscape were established, and engineering adjusting modes and methods of reclaimed farmland landscape reconstruction are put forward in this dissertation. The main research contents and conclusions are as follow:

1. The evolvement rule of landscape pattern of general farmland is revealed by analyzing the history literature and the landscape process of two types of dry farming areas in the north of China. The formation of farmland landscape pattern has many reasons such as its history, nature and humanity, and therefore it is fairly complicated. The farmland landscape pattern is the representation of mankind and its environment spatial distribution differences, which is formed by jamming. The different scales, shapes, structures and quality are resulted from the interaction of various complicated conditions between nature and society. At the primary stage of farmland building, farmland landscape pattern reveals the characteristic of adaptability to the natural environment. Along with the advance of human production technology, farmland landscape pattern embodies the harmony between human and nature. Under such process, farmland landscape pattern has roughly gone through the process of short-term or fixing a day and over a long period of time

concentrated links piece farmland, compounded intensive farmland and precision agriculture. And changes of farmland landscape pattern can reflect the development of society and the progress of science and technology.

The landscape pattern evolvement rule of general farmland was validated through analyzing the landscape pattern indexes of different periods of Zhongjie Friendship Farm. The characteristic of farmland landscape indexes is as follows: PD (Patch Density), LPI (Largest Patch Index), AREA and PERIM (Perimeter) have negative correlation with farmland intensivism level, the higher the farmland intensivism level, the less these indexes. ED (Edge Density) has a relationship with the patch scale and amount, when area is certain, the higher the PD, the bigger the ED, while PD is certain, the bigger the AREA, the less the ED. At a certain zone, when PATCH increases, PD and ED will decrease.

PARA (Perimeter-Area Ratio) will decrease with the increasing of AREA, which illustrates that the number of edge per area will decrease with the increasing of area. LSI (Landscape Shape Index) of scatter farmland is relatively bigger, and shape is irregular. However at the condition of mankind interfering, shape is basically regular, and the index of SHAPE is close to 1, i. e., the shape is or is near square, having the evidence of manpower carving. FRAC is close to 1, which illustrates that the shape is simple and near regular square. PARA should have its rationally upper limit and utilizing-scale lower limit that depend upon the natural condition, economic condition and the culture background. PARA of dry land is higher than that of paddy field. AREA has positive correlation with PERIM, negative correlation with PARA; SHAPE has positive correlation with FRAC.

2. The evolvement rule of landscape pattern and relationship among landscape indexes of mining coal subsidence reclamation farmland are discovered through analyzing the characteristics of landscape pattern of coal area in Xinglongzhuang of Yanzhou city before and after land subsidence and reclamation. Under the disturbance of underground mining to farmland in coal mine area, farmland landscape process and pattern are determined by some factors such as excavation shape, coal thickness, mining depth, coal obliquity, groundwater elevation and roof strata management, and ponding, sloping farmland and crack are the main patterns of the farmland landscape after coal mining.

Up to 2003, Xinglongzhuang town has been mining coal for 22 years. Farmland landscape patterns go generally along with the mining progress, which will gradually lead to subsidence of the earth's surface, to the level farmland changing into sloping lands and ponding, and with the increase of mining progress and mining scope, the shape of farmland patch of unsubsidized land is regular, the edge is in order, the corridor is damaged and can not work smoothly. The main subsidence area mainly evaluates the landscaping of perennial ponding, seasonal ponding and sloping land, among which ponding area accounts for 68.6%. The average patch area of unsubsidized farmland is 4.03 hm^2 ; SHAPE is 1.17; PERIM is 937m; PARA is 326 m/hm^2 ; FRAC is 1.06. The main indexes of unsubsidized patch are: AREA 156.58 hm^2 , PERIM 6600 m, PARA

42.96 m/hm², SHAPE 1.30, FRAC 1.04. Through comparing, the author concludes that the patch shape of the land after subsided approximates square; the slope of coal layer is even; the shape of subsidence land is approximately corresponding with the boundary of underground mining; coal mining has greatly damaged the farmland.

With the spreading of mining subsidence scope, decrease of patch density, increase of patch area and its perimeter, and decline of intensivism level of farmland; the landscape shape index (LSI) of the subsided farmland is relatively big, and its shape is irregular. The landscape shape index is still close to 1, and the connection degree of unsubsidized farmland with the corridors in other town is very low, with higher corridor density, bad connection degree, lower utilization, and little capital investing for reclamation. Farmland landscape lags behind compared with the farm equipped with high degree mechanization, with an obvious gap with SHAPE and FARA.

3. The adjusting and controlling mode, method for the reclamation farmland landscape restoration are put forward through investigating and analyzing the current reclamation projects. The main direction of land reclamation in coal mining area is ecology restoration to give the priority to cropland for which can harmonize the benefit of society, economy and ecology and keep the society of mining area sustainable development.

The object and content of reclamation farmland landscape reconstruction design and planning are different from the general landscape. Organizing space pattern of patch/corridor and reconstruction technology of matrix are its nuclear content. "3S" technology development has provided research means and technical support for farmland landscape planning and design, and has promoted the modernization of farmland landscape research and farmland landscape planning and design.

Reclamation farmland landscape reconstruction need be realized by engineering projects, which make reclamation soil achieve the most excellent productive force. According to the requirement of landscape reconstruction, this dissertation designs the method of "surface soil peeling off in digging deep to fill shallow band reclamation", "terrace mode surface soil peeling off", and surface soil peels off technology ecology reclamation in advance.

Taking project charge of land reclamation in Hebei and Shandong Province as examples, the structure of project charge was analyzed in detail. According to the sensitivity of project charge, its order is land leveling project, farmland irrigation project, field road project and other projects. Four control countermeasures are put forward in order to decrease land reclamation charge.

In the present synthetical analysis of property right of coal mine areas subsidence land, this dissertation expounds on the exist questions and causes of property right of coal mine areas subsidence land, and puts forward mode of "mend to take the place of levying", mode of "property right to cut apart and combination", combining with land property right theory.

4. According to the requirements of sustainable utilization, the reclamation farmland landscape quality evaluation system is established. The landscape quality of reclamation farmland includes its producing capacity, health level and aesthetics worth. Considering the current status and

development of reclamation farmland landscape, the author takes the land production, land environment health, sightseeing and tour function as evaluation standard to set up the quality evaluation system of land reclamation farmland landscape on small-scale coal mining subsidence. The index system mainly includes landscape productivity, landscape health level and landscape aesthetics worth. By means of inner insert median method, five grades of quality evaluating standard is established. Based on single farmland landscape index evaluating, adopting method of weight sum calculates comprehensive quality index, and comparing with quality evaluating standard, the quality of reclamation farmland landscape is obtained.

In this dissertation, the author gives a typical case of landscape reconstruction of reclaimed farmland at the coal-mining subsided land of Xinglongzhuang Town, Yanzhou City. By appraising to the soil productivity, installation level, biodiversity, soil environment quality, comfortable degree and landscape civilization value of the reclaimed farmland, and analyzing the landscape productivity, landscape health and aesthetics value of the reclaimed farmland, it can be concluded that the landscape reconstruction of the reclaimed farmland is not ideal, existing some shortcomings. At present, this phenomenon exists universally in land reclamation project. Therefore, it is needed to combine ecology reconstruction with planning and design, surface soil peeling and property right distribution. At the same time, the author proposes some measures that should be taken, such as, increase of organic fertilizer, disposes of the plant reasonably, exertion of the property right distribution, development of water-saving agriculture projects step by step, and so on, based on the similar reclamation items of coal-mining subsided land at Xinglongzhuang Town.

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