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Rehabilitation of Degraded Land Ecosystems in Southern Shaanxi Province: An Introduction to a Sino-German Project
中德合作“陕西南部退化土地生态系统修复研究”项目介绍

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Abstract

The Chinese Government is making multiple efforts to protect water resources in the south of the Shaanxi Province, as land ecosystems have been degraded due to inappropriate land use and deforestation. Rehabilitation of degraded lands is an option which offers potential commercial value as well as important ecological benefits. Therefore, the presented Sino-German project was initiated with the overall objective to develop and demonstrate a "land use planning system” for a sustained land use. Information to support the development of the planning system is largely gained from three field experiments on erosion, rehabilitation measures, and assessment of forest resources in addition to a study on socioeconomic assessment in the study area. The conception of the project is based on the assessment of the prevailing situation (erosion of various vegetative covers, forest resources, and socioeconomic conditions), evaluation of rehabilitation measures employed to improve the situation, and the development of the planning system. The land use planning system will provide a range of prospective possibilities to improve the soil and water conservation in the region. Taking into account the particular economic and social considerations, a priority list of areas, where urgent actions must be taken, can be compiled. In addition, recommendations for appropriate land use can be formulated. The application of the land use planning system will enable planning authorities to be familiar with new planning tools, which can be used to achieve a sustainable improvement of the environment and of the living conditions of the local inhabitants.

摘要

中国政府采取了一系列的行动对陕南秦巴山区由于长期以来不合理的土地利用和森林破坏所导致的水环境退化进行保护。对退化山地生态环境进行系统修复是一项可行的措施，不仅发掘了其潜在的经济价值，也优化了生态效益。因此，这项中德合作研究项目的总体目标是开发和示范一个着眼于可持续土地利用的“土地利用规划系统”。规划系统所需的大部分基础数据来源于三部分野外实验，其分别为侵蚀实验，修复措施实验和森林资源评估，此外还有一部分社会经济学研究。本研究项目的理念首先是基于对目前研究区概况的评估（不同植被类型下的水土流失，森林资源和社会经济状况），对所应用修复措施效果的评价以及最终规划系统的开发。土地利用规划系统的开发将为区域水土保持生态修复带来一系列的积极效应。在充分考虑特殊社会和经济因素的前提下，那些急需采取修复措施的区域将会被区分出来，而且也可以进一步给出合理的土地利用建议。该土地利用规划系统的开发有助于决策部门熟悉和掌握现代的管理工具，从而达到改善研究区生态环境和提高当地居民生存质量的目的。

1 Introduction

Multiple attempts have been made by the Chinese Government to improve the environmental situation in China. However, the country’s overall sustainable development is endangered due to: increased soil erosions, critical water environment situation due to excessive sedimentation and agrarian pollutants in water streams, raising natural catastrophes of floods and landslides with significantly shorter intervals, and the hazard of poverty of the rural communities as a result of the decrease in land fertility and productivity. The causes of this critical situation are, concisely, inappropriate land use, deforestation, and mining over the last century.

However, there are several possible avenues to overcome these challenges, such as:

- conservation of natural resource as undertaken by the Chinese Government
- promoting agronomic practice, production, and processing systems that are environmental friendly while in the meanwhile secures sustained income for rural communities
- developing sustained land use systems that meet the interests of both the government and the rural communities and which enable sustained income for rural inhabitants while in the meanwhile aims at safeguarding human health as well as environmental quality

Sustained land use systems can be achieved by several selective measures such as, rehabilitation of degraded lands, afforestation of areas susceptible to erosion, sustainable management of forests, agroforestry, and/or organic farming or integrated agriculture.

The approach of the Sino-German Project “Rehabilitation of Degraded Land Ecosystems in Southern Shaanxi Province” is to develop a “Land Use Planning System” for an environmental landscape management. This will enable decision makers to introduce

integrative planning techniques, of which the main objectives are to:

- enhance the environmental landscape management, taking into consideration the ecological, economical and social aspects, and
- improve the surface water quality through reduction of soil erosion.

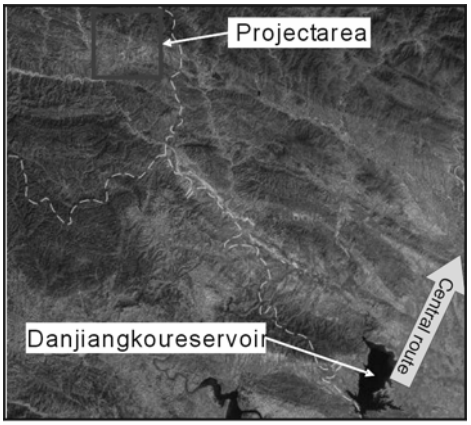

Figure 1: The study area in the Shangnan County in Southern Shaanxi Province

The project is located in Shangnan County in the south of Shaanxi province (Figure 1). The southern Shaanxi province is of special interest due to its role in diverting water to Beijing within the frame of the South-to-North Water Diversion Project.

In the south of the Shaanxi Province, soil erosion increased rapidly over the last decades (Xi et al. 1997, cf. Figure 2). Soil loss in the region is estimated at 4000-7000t/km^2/year (Wang et al. 2003). The consequence is raising natural disasters of landslides and floods with considerably shorter intervals of an average of 5-year since the middle of the 20th century, compared to 28-year before this time (Wang et al. 2003). The main reasons for this deterioration are deforestation, and inappropriate land use (Xi et. 1997).

Figure 2: Degradation of forests in the south of the Shaanxi Province

The former ecosystem in the region embraced 246 woody species from 60 families. Over the last century, the natural forests have been strongly degraded or deforested (Zhang 1986, Jia 1984). The forest coverage decreased from 64 percent to 46 percent compared to the 1950s. Most of the remaining forests are of poor quality or were turned to coppices, bushes, and even grasslands. Average growing stock is estimated at only 7 to 9 m^3/ha, which is far from its potential. The plantation forests in the region comprise mainly one species and are experiencing structural deficiencies with low stability and sensitivity to disturbances.

2 Scientific Approach

Particularly, the widespread erosion occurrence, connected with increased surface discharge of polluted water in the south of Shaanxi province forced actions to be taken. Rehabilitation of the degraded lands is an option, which offers potential commercial value as well as important ecological benefits. Therefore, the presented Sino-German project was initiated with the overall objective to develop and demonstrate a "land use planning system" towards sustainable land use. For the realisation of this objective, the research approach is integrative, as the project includes three linked main tasks (Figure 3). Task I includes an experimental component of three different field experiments [Ia) erosion, Ib) afforestation, Ic) assessment of forest resources]. Task II involves a socioeconomic survey in the study area. Both tasks are associated with a system-analysis component on modelling and development of a reliable planning system (Task III).

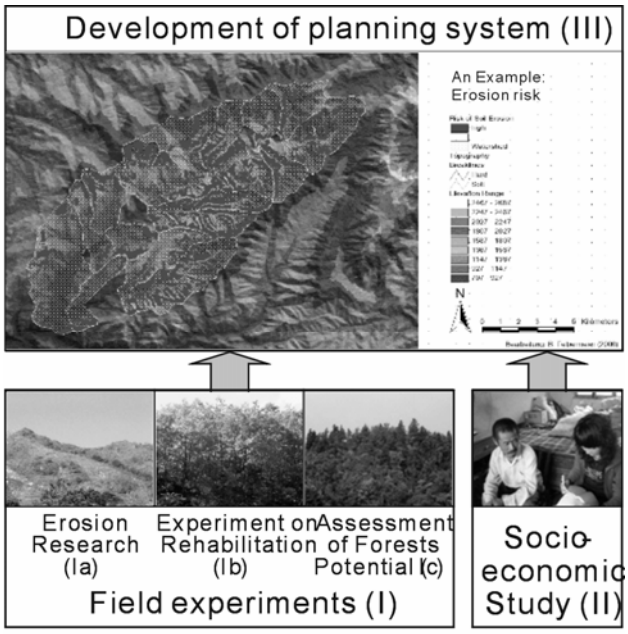

Figure 3: Project tasks

The different project tasks are conducted to pursue the following research questions:

Task Ia:	What is the degree of erosion and surface run off on the different vegetative covers?
Task Ib:	Is afforestation necessary for the rehabilitation of abandoned farm lands?
Task Ib:	Which degree of success/failure, on the short and medium-term, does each of the investigated tree species have in the afforestation of abandoned farmlands?
Task Ib:	Under which site conditions can a successful afforestation be practiced on abandoned farmlands?
Task Ib:	Which short and medium-term impacts does afforestation have on soil and vegetation on abandoned farmlands?
Task Ib:	Which site preparation techniques for each of the investigated tree species is ecologically and economically feasible and can be practised on abandoned farm lands on a large scale?
Task Ic:	What is the potential of wood in mass and regeneration in quantity and quality in the high forest?
Task Ic:	What is the potential of the forest resources to support the reduction of excess atmospheric carbon dioxide and of poverty?
Task II:	What is the degree of acceptance of the local inhabitants to changing the conventional land use in the study area
Task III:	Which ecological enhancement particularly due to rehabilitation technologies can be achieved by land use change?
Task III:	Which impacts of land use changes on socioeconomic conditions can be expected?
Task III:	How can the land use be optimized with regard to the objectives of the sustainable water resource management?

The activities associated with the research questions include:

1) The assessment of the prevailing situation of the erosion using all available results from published studies in addition to establishing experimental plots to estimate the sediments and runoff of the different land use structures in the study area.
2) The assessment of the potential of the available forests in order to provide recommendations on the sustainable management of the forest resources.
3) The assessment of the socioeconomic conditions in the study area to detect their relationship to the prevailing environmental quality and to ascertain whether altering the traditional land use can be accepted by the local inhabitants.
4) The evaluation of rehabilitation measures aiming at the ecological and economical enhancement of the different land use structures in addition to establishing permanent experimental plots, which can be used for demonstration, educational and training purposes.
5) The transfer of the results of field experiments from the level of the research plots to spatial management units.
6) The development of the land use planning system using the results and information collected from the different field experiments, spatial information as well as from the available publications and socio-economic studies.

3 Methodologies

3.1 Field experiments (Task I)

Figure 4: Dominating vegetative covers in the study area

The field experiments include the most frequent land use structures or vegetative covers in the study area (Figure 4). The study is conducted on the dominant yellow-brown soil (84%) in the study area.

The field experiments (Figure 5) deal with:

a) Estimation of soil erosion and runoff on the different vegetative covers in the study area
b) Rehabilitation of degraded lands by afforestation on grasslands
c) Assessment of the potential of forest resources (coppices and plantation forests).
d)

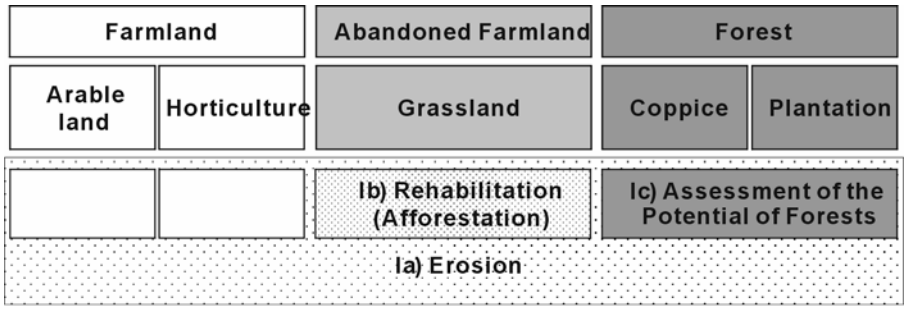

Figure 5: Field experiments on the different vegetative covers

3.2 Layout of the field experiments

Research on erosion (Task Ia) is conducted on 5 vegetative covers (Figure 5). Each vegetative cover includes 7 plots having different slope steepness, ranging between 10° and 40°. Plots (Figure 6) are used for collecting data on erosion and runoff after each rain event during the rainy season. Zhang 2005 conducted a primary study including nine plots using a similar technique. This study revealed that the technique is appropriate for the measurement of erosion in mountainous areas.

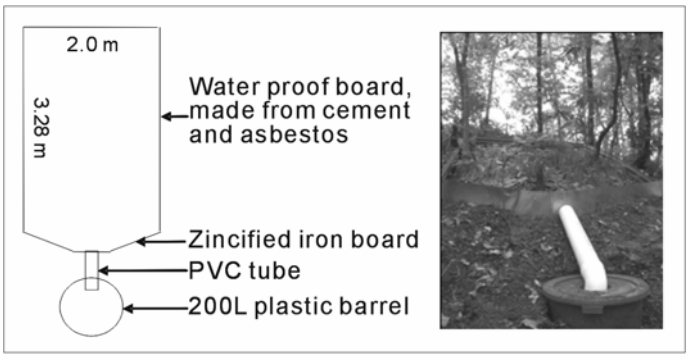

Figure 6: Layout of a plot in the erosion experiment (Task Ia)

Rehabilitation measures (Task Ib) are practiced on grasslands. Three grasslands in the

study area were selected. On each a block is laid out. A block includes a control plot without any treatment and 4x4 Latin Square. The control plots (Figure 7) are installed for long-term observation on ground vegetation and woody regeneration in order to follow the development in the successional processes.

The 4x4 Latin Square, including 16 units, is used for planting of four indigenous tree species of economical and ecological importance (*Quercus variabilis, Pinus massoniana, Acer truncatum, and Pistacia chinensis*). Each unit is subdivided into two subunits. Each subunit randomly receives one of two levels of site preparation related to reduction of the competitive impact of the ground vegetation: no clearance of ground vegetation, or annual frequent clearance of ground vegetation over a period of 3-5 years. The underlying statistical design is 4x4 Latin Square with subunit treatments arranged in a Split-Plot Design (Figure 8). As the control plots, the Latin squares are permanently installed and can be used for further medium to long-term investigations, and serve demonstration and educational purposes.

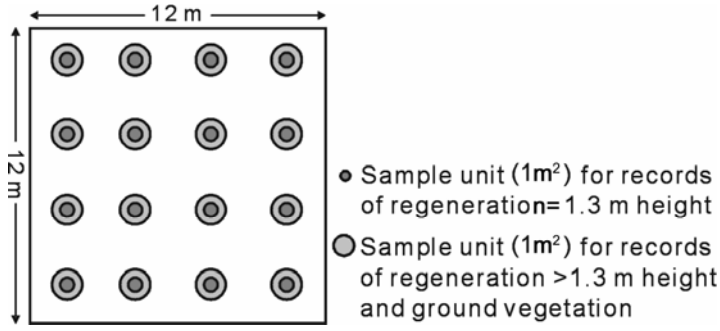

Figure 7: Layout of a control plot in the rehabilitation experiment (Task Ib)

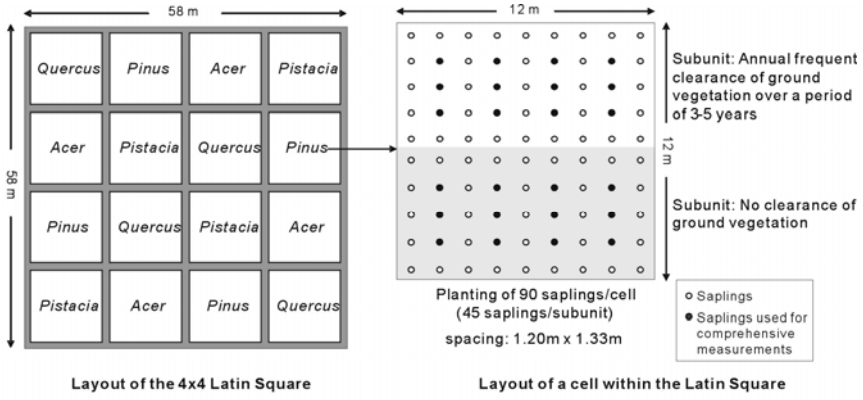

Figure 8: Layout of 4x4 Latin Square in the rehabilitation experiment (Task Ib)

Planting will be achieved by 90 saplings unit^{-1} (45 saplings subunit^{-1}). The reason for

this high initial density is that saplings over the observation period will be collected for biomass and root investigations.

For the assessment of forest resources (Task Ic), 40 stands are randomly selected in either coppices or plantation forests within the study area. A plot of a size of 20mx20m is installed in each stand. Plots are used for collecting information about the status of the mature stand (on the whole plot) and natural regeneration as well as ground vegetation on systematically distributed sample units on each plot (Figure 9).

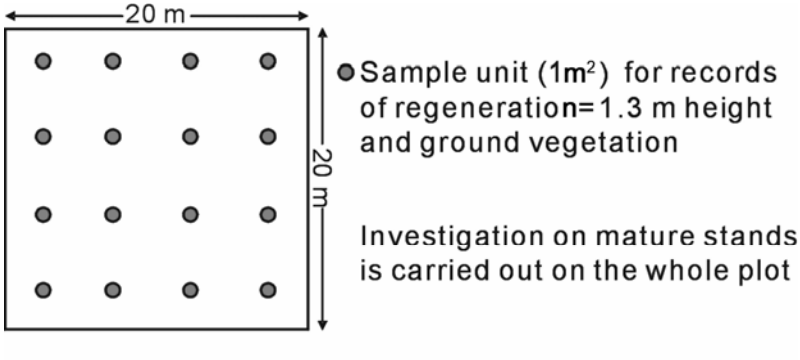

Figure 9: Layout of a plot in coppices and plantation forests (Task Ic)

3.2 Outline of the statistical analyses techniques

According to the designs of the field experiments (Task I), the research hypotheses can be evaluated by means of statistical tests of the null hypotheses using the ANOVA, as the simplest technique employed in the analyses of the collected data. However, there is an interest in testing multivariate hypotheses and in assessing the changes among the various measurements taken over the observation period. Therefore, the simplest univariate hypotheses used in the ANOVA will be reconstructed according to the desired statistical analyses and hypotheses testing. These will include univariate and multivariate analyses of variance and covariance as well as repeated-measures analyses of variance (Bortz 1985, El Kateb et al. 2004, Littell et al. 1991). For discrete variables, multivariable analysis of categorical data techniques (Fienberg 1979, Grizzle et al. 1969, Kleinbaum et al. 1988) will be used.

In addition, the designs of the experiments are set flexibly to allow conducting simple and multiple regression analyses to develop models describing the relationships of interests. Furthermore, comparing regression equations of, for example, the different vegetative covers or the different tree species, is meaningful to adequately describe relationships of interest, as for example, precipitation and erosion on the different vegetative covers or diameter and under ground biomass of saplings of the different tree species.
The assumptions underlying a design and the validity of models will be examined using

residual analysis and different statistical tests (Cochran and Cox 1992, Draper and Smith 1981, El Kateb 1991, Kleinbaum et al. 1988, Kirk 1995).

Finally, the comprehensive statistical analyses will provide reliable information concerning all research questions related to the field experiments. This will considerably enhance the accuracy of the land use planning system.

3.4 Socioeconomic assessment (Task II)

Socioeconomic questionnaires (Task II) will be conducted on 200 households in the study area. The questionnaires take into account the following aspects: land use, usage of timber and non-timber products, energy sources, knowledge about the hazard of inappropriate land use, soil and water conservation, efficiency of collaboration with local authorities, and other social and environmental aspects.

For the analysis of the socioeconomic data, descriptive statistics, cluster analysis, and regression analyses will be performed to describe the socioeconomic variables, to group the households into clusters, and to identify relationships between the socioeconomic variables and the environmental quality in the study area, respectively.

3.5 Land use planning system (Task III)

The concept of the land use planning system lays emphasis on the development of proposals for land use management plans, which are derived from land use options defined by decision makers (Figure 11). The development process of the system employs the data and results of the Tasks I and II (Figure 10). It includes the following work packages:

- Collection of observation data:
  The results of the field experiments (Task I) and the socioeconomic study (Task II) will be aggregated, remote sensing data of the study area will be analyzed and interpreted, and information from the Chinese administration will be acquired.
- Collection of modelling tools:
  A set of tools for the simulation of management options will be assembled. This includes the adaptation of already existing models as well as the application of models of erosion and forest development derived from Task I.
- Simulation of management options:
  Different management options will be defined in collaboration with Chinese decision makers and will then be simulated for the study area.
- Planning tools:

Finally, different planning tools from operations research and spatial science will be developed to assemble proposals of land use management plans based on the defined management options and the objectives of the Chinese decision makers.

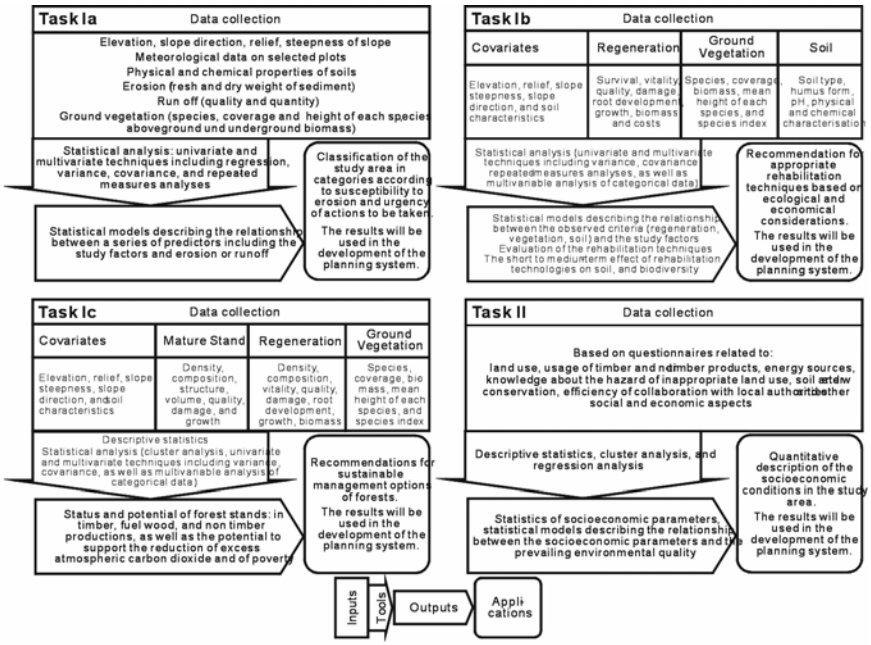

Figure 10: Inputs, tools, outputs and applications of results of Task I and Task II

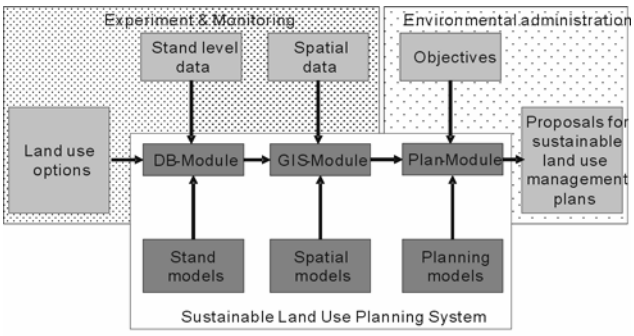

Figure 11: Structure of the land use planning system (Task III)

The development of the system will be supported by a team composed of Chinese experts and decision makers, in order to secure the congruence between the project team and subsequent users. The layout of the planning system (Figure 11) will contain three

modules to implement the workflow from science to application. Time series of the defined management options will be stored in a relational database module. This information will be associated with the spatial information available for the study area and will be stored in a geographic information system module. Finally, user requirements and planning instruments are combined in the plan module. Using this plan module, decision makers or system users can submit proposals for land use management plans on a scientific basis.

4 Results and their Applications

The collected data from the erosion research (Task Ia) will be used for developing models describing the relationship between a series of predictors including the study factors and erosion or runoff. This in turn enables the classification of the study area in categories according to susceptibility to erosion and urgency of actions to be taken.

The investigations carried out on the control plots, where no afforestation is implemented, in the rehabilitation experiment (Task Ib) will provide information about the natural regeneration of the woody vegetation and its development and, thus, support the decision making of the indispensability or dispensability of the afforestation measures.

The results (Task Ib) will help providing recommendations, based on ecological and economical assessments, for appropriate forestation in the study area and in areas of a comparable situation, which are widespread in the south of the Shaanxi Province. The recommendations will be compiled in a brochure to be introduced to authorities, scientists, and consultants dealing with rehabilitation of degraded lands.

The permanent plots of the afforestation experiment (Task Ib) can be used for further medium to long-term investigations, as the effect of tending and thinning techniques on growth and quality of young stands and, hence, serve demonstration, research and educational purposes.

The outcomes of assessment of forests (Task Ic) will provide information about the potential of the stands and the availability of regeneration and its growth potential. This can be used to assemble recommendations either for conservation efforts or for sustainable management options to improve the stands mass and quality or to improve the development of the natural regeneration. In addition, information about the potential of non-timber products and the potential to support the reduction of excess atmospheric carbon dioxide will be gained to support evaluating the management options.

The results of all field experiments (Task I) will be used in the development of the land

use planning system.

The socioeconomic survey (Task II) will provide information about the traditional land use practice, usage of timber and non-timber products, energy sources, knowledge about the hazard of inappropriate land use, and the degree of acceptance to changing the conventional land use practices. In addition, relationships between the prevailing environmental conditions and socioeconomic parameters can be detected. This valuable information will be considered in the land use planning system in order to develop strategies for the regional sustainability.

The planning system (Task III) will be used to achieve the research objectives and to support the transfer of the scientific findings into China's environmental planning. The land use planning system will enable detecting a range of prospective possibilities to improve the soil and water conservation in the region. Taking into account the particular economic and social restrictions, a priority list of areas where urgent actions must be taken, can be compiled. In addition, recommendations for appropriate land use can be formulated. The application of the system will enable planning authorities to be familiar with new planning tools, which can be used to achieve a sustainable improvement of the environment and of the living conditions of the local inhabitants.

Acknowledgments

The presented project is being funded by the German Federal Ministry of Education and Research (BMBF). Grateful acknowledgment is given to the BMBF for funding the project, to the German Academic Exchange Service (DAAD) for providing Doctoral Grants for two Chinese Students and to the Institute of Soil and Water Conservation, Chang Jiang River Water Resources Commission for the financial contribution to conduct the research work in the study area.

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