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Research Report:

Impact of climate change and variability on local-scale land use, Shaanxi Province, China

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Contents

Preface

This report will describe a 2-year research project that started in January 2002. The project has been coordinated by Physical Geography, Dept of Earth Sciences, Gothenburg University (GU), (Deliang Chen, Madelene Ostwald and Katarina Borne), but has been a multidisciplinary collaboration of seven researchers from Human Ecology, Gothenburg University (Per Knutsson), Dept of Physical Geography and Ecosystem Analysis, Lund University (Sara Brogaard), Potsdam Institute for Climate Impact Research (PIK), Germany, (Youmin Chen – presently at GU) and Dept of Resources and Environment Science, Beijing Normal University, China (Xie Yun).

The idea of the project was a result of a discussion between Madelene Ostwald and me in 2001. After the discussion a proposal was drafted and sent to Sida. Although I have been the main applicant of the proposal to Sida, Madelene Ostwald has taken the main responsibility for the operation of the project. Due to the multidisciplinary nature of and many participants of the project, the coordination work is challenging. However, I feel, and I believe all the participants of the project agree with me, that Madelene Ostwald has done a great job in making the project a successful one. Needless to say, all the participants have played an active role in contributing to the success of the project.

Any project which deals with works in a foreign country needs a lot of local help and assistance. There is no exception to this project. As will be mentioned in the acknowledgement section, many organisations and individuals in China have helped us in achieving the goals of the project. In particular, The Laboratory of Climate Studies, China Meteorological Administration and Department of Resources and Environmental Sciences, Beijing Normal University, have helped us in many ways. We have established a close relation with these two originations through this project. I see this relation as one of the most important outcome of this project as it is crucial for a successful study in China now and in the future.

At the end of the project, we have also benefited from another China project supported by STINT (The Swedish Foundation for International Cooperation in Research and Higher Education) granted to me with Gothenburg University, National Climate Center, China Meteorological Administration and Department of Resources and Environmental Sciences, Beijing Normal University as participating organisations. This project provided us with the possibility to keep the momentum of the cooperation and to have some personnel exchanges between the Swedish partners and the Chinese partners.

Deliang Chen, 22 February 2004 at Gothenburg University in Sweden.

1. INTRODUCTION

1.1. Climate change and land use in China

Processes associated with climate change are highly relevant for China since the country is very dependent on the climate and susceptible to climate change (Smit and Cai 1996). The impact of climate change on agriculture has been part of the national key project (National Climate Centre 2000). The area of Loess Plateau is located in the divide between the monsoon and the non-monsoon zones, which makes that area very sensitive to climate change and variation. The summer monsoon reaches northern China in the middle of July and starts its retreat already in the middle of August. It is during this period that the region receives most of the annual precipitation. If the monsoon is weak, giving a short duration in the northern part, it certainly means drought for this part of China (Ding 1994). Serious damage to the economy, agriculture and human life is associated with drought as well as floods caused by climate variability (Huang et al. 1998). One of the worst natural disasters on record was the great flood of the Yangtze River in the summer of 1998. Yet, the previous year in northern China experienced record drought (Lau and Wu 2001). IPCC has reported that this part is likely to experience a warming of 3°C and increase of precipitation with 7% by year 2050 (IPCC 2001). For the area of the Loess Plateau, where the rainfall is low already, the increase in temperature would decrease the soil moisture and lead to severe water-stress condition.

Hosting over a fifth of the world's population on 7% of its land mass makes food security and hence land use a relevant and important issue for China, an issue that has been greatly ventilated in research over the last decade (Yang and Huang 1997; Heilig et al. 2000; Yang and Li 2000). China is at the same time undergoing a dynamic phase in its development with an economic growth of 9.8% from 1978-1995; hence a dramatic change in environmental, social and economic aspects has being taking place (Skinner et al. 2001). The starting point for these changes can be traced to the 1978 economic reform that opened up to the outside market-world under controlled forms, a change forced by years of economic stagnation (Lu and Wang 2002). This reform, the Open-Door Policy, made China taking part in the increased globalization (Yeh and Li 1999) with increasing trade of agricultural products. This was further accentuated with the land reform of 1982, the Household Responsibility System, in which the agricultural communes were resolved and the land-use rights were distributed to individual farmers on lease for 15 years. The effects of these two reforms have had a significant impact on land use. During the last decade, an increased concern for the environmental effects of these reforms and policies has been highlighted (McElroy et al. 1998; Skinner et al. 2001), particularly in the Loess Plateau which is the focus for this particular study (Hu 1997; Goubin 1999; Liu 1999; Skinner et al. 2001). Short-term land-use responsibility with the 15-years leases and the market possibilities have increased environmental degradation, e.g. abandonment of damaged land (Yang and Li 2000) and increased soil loss and erosion that in turn causes sedimentation problems of the Chinese rivers. As a response, the Chinese government introduced the Cropland Conversion Program (CCP) in 1999 with the expectation to minimize the cultivation of crops in slope areas by encouraging farmers to plant trees and grasses instead (Rui et al. 2001), resulting in a decrease of arable land. This also included compensation to farmers in terms of money and food grains for up to 8 years. A diminishing trend of arable land has been seen since 1978 with a national trend of -5% from 1978 to 1996, while Shaanxi Province experienced a decrease of 12% over the same year based on statistical data (Yang and Li 2000). During the 1980s and 1990s, the study area of Ansai has been an agricultural subsistent farm area where grown crops have been millet, maize, sorghum, potato, buck wheat and vegetables (Chen et al. 2001).

1.2. Study area and related background information

1.2.1. Natural and geographical conditions

China has a complex and diverse topography, mainly consisting of plateaus, mountains, basins, plains and hills. The land elevation decreases from west to the east (Hsieh 1973). Looking at these differences from a climatic point of view, the 105°E boundary is a very significant dividing line (Domrös and Peng 1988). It divides the monsoon and non-monsoon zones, which makes our area very suitable in terms of impact of climate change influenced by the alteration of the monsoon. The divide is affected by the huge continental landmasses and the Pacific Oceans water bodies. The circulation in China can be summarized into an anticyclonic field prevailing from Sep/Oct to April/May, and a cyclonic field between May/June to Sep (Domrös and Peng 1988).

The province of Shaanxi can geographically be divided into three regions. The central region of Guanzhong, dominated by the province capital of Xi'an, has around 60% of the province's population and even more of its produced output. The southern region of Shaanan is a mountainous zone, sharing more in common with Sichuan, as it is characterized by agricultural production of rice, silk and tea. The northern region of Shaanbei, in which the study area is located, borders the deserts and sandy hills of Inner Mongolia. It is the poorest region in Shaanxi Province, with low agricultural production and sparse population. Shaanxi Province is within the Loess Plateau (fig. 1 a) where wind-deposited loess soil is predominating. The soil is classified as Calcic Cambiosol (FAO-UNESCO 1977). This soil is weakly resistant to erosion (Wang et al. 2001). Ansai County is in the northern part on Shaanxi (fig. 1 b).

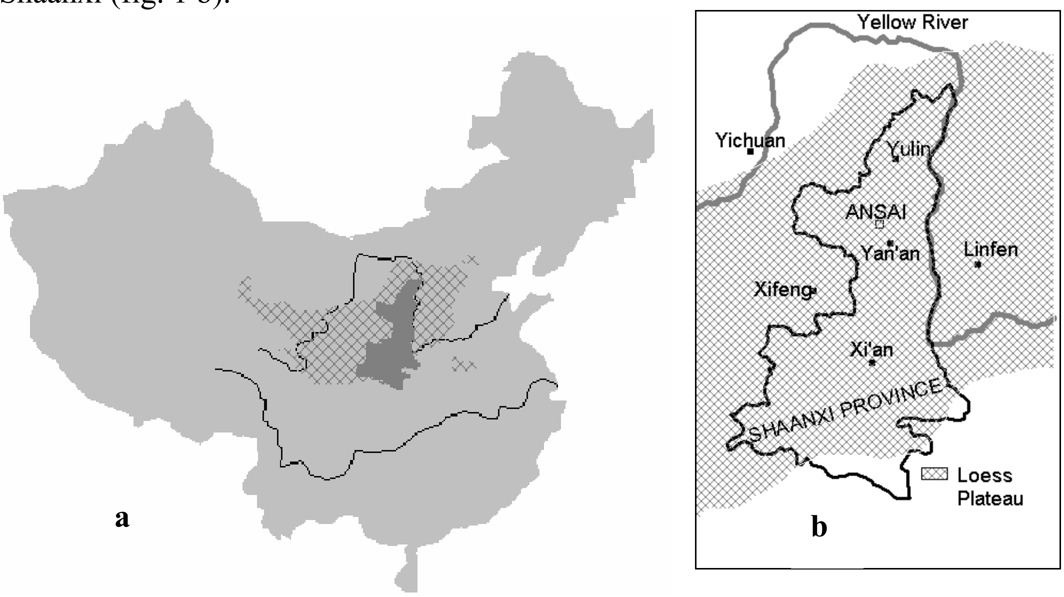


Figure 1: a) The area of Shaanxi Province and the Loess Plateau. b) Shaanxi Province with county seat Town Ansai indicated.

Danangou watershed (36°53'N; 109°19'E) is located 7 km north of Ansai town; the seat town of Ansai County. Danangou consists of two villages, Danangou and Leipingta (fig. 2 a) and covers an area of 3.5 km2. The main valley of the watershed has an altitude ranging between 1000-1350 m.a.s.l.

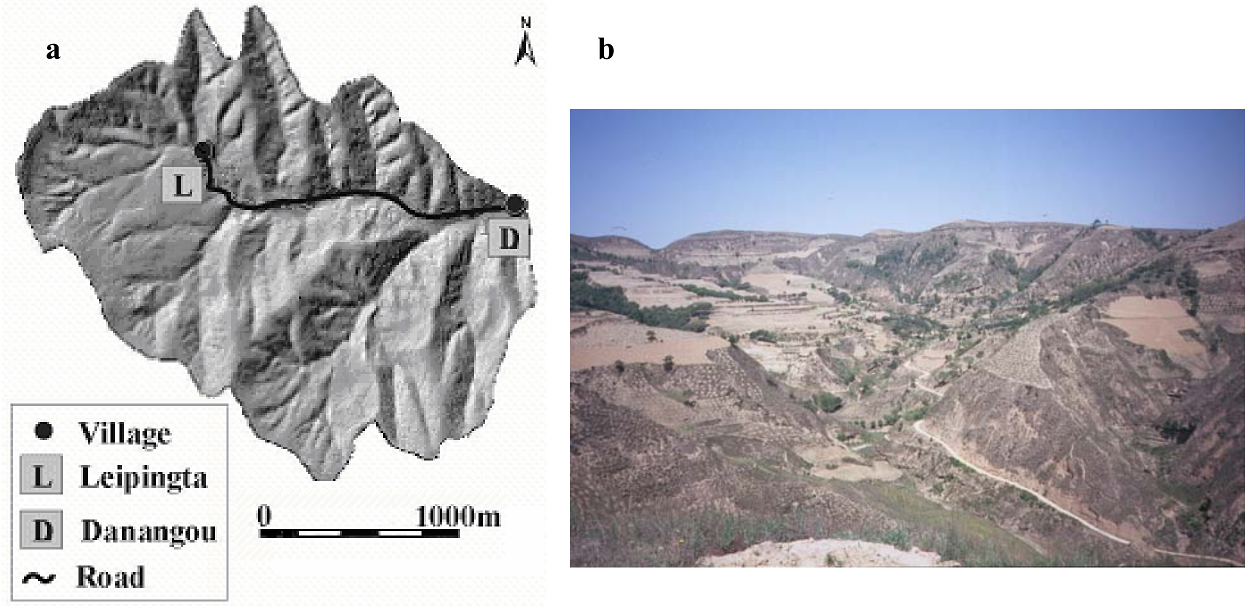


Figure 2: a) The focus of the study area, Danangou Watershed with its two villages. b) Photo over Leipingta.

1.2.2. Social and political setting

Ranked according to the Gross Domestic Product (GDP) per capita, Shaanxi was China's third poorest province in 1998. In 1996, only five provinces had a higher incidence of poverty than Shaanxi. Four out of these five provinces are, like Shaanxi Province, located in northwest China (Démurger et al. 2002). In a historical perspective, Shaanxi's development is characterized by the contrast between its profound cultural heritage of the great dynasties of the early Chinese empire, its important role as the cradle of the Chinese communist revolution in the 1940s and gateway to the northwest during the planning period of the 1950s, 1960s and 1970s, and its new role as poor province searching for comparative advantage relative to the dominant east in an evolving market system (Watson et al. 1999).

Despite the fact that the study area is located in the poorest region in one of China's poorest provinces, the households in Danangou and Leipingta villages has since the early 1980s been confronted with far reaching processes of policy and socio-economic changes. Firstly, starting in 1978, the Household Responsibility System contracted land to every peasant household in China on the basis of family size and farmers were given the right to till the contracted land for 15 years. This system replaced the collective agricultural production in so called production teams of the 1960s and 1970s. The Household Responsibility System is a kind of tenant-farming system where collective ownership of land is combined with private ownership of capital, household user-rights of land, and right to dispose of its residual income (Peng 1999). Presently, township and village-committees represent the collective ownership of land in China, but rights of these two institutions are restricted to making land readjustments among the farmers (Hu 1997). In 1993, a new policy was adopted that allows land contracts to be extended for another 30 years when existing 15 year contracts expire (Albersen 2002; Xiwen 2002). Further, land can be subleased for a fee to other households if a farmer has non-farm job and gives up farming. The household can now also hire temporary workers for farm work. These policy reforms have subsequently resulted in the re-emergence of land and labour markets in rural China (Lin 1997). In the study area, the Household Responsibility System was introduced in 1982.

Secondly, the Household Responsibility System can be seen as a response to the failed heavy industry- and urban development-oriented Chinese economic policy since the 1950s (Galbraith and Lu 2000). Through this reform, the Chinese government aimed not only to increase agricultural production, but also to increase incomes that could form a demand to other industrial sectors. To facilitate reform in the agricultural as well as light industry sectors, China also began to reform its centralised and rigid commerce. More autonomy was granted to wholesale and retail, food services were transferred or leased to communities or individuals, the agricultural price system was reformed and prices were adjusted up. Further, in 1979 the well known Open-Door Policy was initiated, including the opening up of geographical regions to foreign investments and decentralization of foreign trade. From being a closed economy in the 1970s, by 1995 China had become the world's 11th largest trading country (Galbraith and Lu 2000).

On a national level, the economic impacts of these reforms have been dramatic. From 1978 to 1984, agricultural output increased 126%, while the agricultural share in total GDP grew from 28% to 32% (Galbraith and Lu 2000). Lin (1997) has showed that of the 42% output growth in the cropping sector in 1978 – 1984, about 54% can be attributed to the reforms implemented since 1978. Of this productivity growth, 97% can be attributed to the shift from the production team system to the Household Responsibility System. The Household Responsibility System makes it possible for the farmer to devote his or her land, labour and capital resources to cash crops and sideline occupations. As a result, areas sown to grain have decreased while areas planted to crops have expanded. For example, from 1991 to 1992, purchases of plastic films (increasing sowing time and growing period) in cold and dry areas in the northern part of China increased with 13% (Xiwen 2002).

On the other hand, more and more farmers engage in non-farm activities. The contribution of the agricultural sector to GDP has actually decreased from 32% in 1981 to 15% in 2001 (World Bank 2002). Given the shortage of farmland, increasing capital investment in agriculture exhibits diminishing marginal returns, and labour productivity tends to decline. At the same time the rural non-agricultural sector is increasing, primarily through township and village enterprises (TVE). By 1995 the TVE contributed about 26% of GDP compared to 23% by the agricultural sector (Peng 1999). This development should be viewed in the light of the fact that 62% of China's population is still classified as rural residents (World Bank 2002). Even in a poor province like Shaanxi, the economic impacts of reforms are obvious. For example, the average annual growth rate of GDP per capita in Shaanxi Province between 1979 and 1998 was 7.8% (Démurger et al. 1999). The rural poverty incidence decreased from 41.6% in 1985 to 17.5% in 1996 (World Bank 2000). The agricultural share of GDP decreased from 42.2% in 1978 to 20.9% in 1998 (Démurger et al. 1999). But there are also social impacts. The shift to family farming has weakened the collective functions from town to village, resulting in neglected capital investment in farmland and maintenance of reservoir, irrigation and drainage facilities (Hu 1997). Further, inter-household and gender inequality is increasing (for example Peng 1999; Benjamin and Brandt 1999; Entwistle et al. 1995; Beaver et al. 1995).

Thirdly, due to the severe problems of soil erosion in Shaanxi Province and the national level impacts due to sedimentation of the Yellow and Yangtze rivers, conversion of cropland to forest and grassland was initiated on large scale in the province in 1999. The Chinese government allocated a subsidy of 735 billion yuan based on a conversion target of 800 000 mu (1 mu = 0,0667 hectare) for Shaanxi Province to cover compensation to farmers for converting their croplands. 34 counties in Shaanxi (including Ansai) were designated pilot counties for the new Cropland Conversion Programme. Estimated results of the programme are for example for forest and grassland coverage to reach 80%, and a 69% decrease of sedimentation by 2008. The policy of the programme is that of the trees planted, 80% should be ‘ecological trees’, as opposed to economic/cash crop trees (Rui et al. 2001).

One of the central points of the implementation of The Cropland Conversion Programme is the compensation system. Individual farmers convert cropland by planting trees and grass are compensated through grain, cash and seedling subsidies. However, actual conversion rates in Shaanxi Province have by far surpassed the target set by the central government. By the year 2000, over 3 million mu of cropland had been converted to forest and grassland and in many cases the payment of subsidies has been delayed (Rui et al. 2001). The implementation of the Cropland Conversion Programme contributes to the increasing share of non-farm income to total income in rural Shaanxi. Since households participating in the programme receive grain subsidies, even more of the household labour force can be allocated to non-farm activities.

1.3. Objectives and research questions

The aim of the project has been to document the climate change and variability in the specific area in Shaanxi Province, China, during the past 50 years and to investigate their impact on local-scale land use in the area exposed to monsoon climate. This should be seen as a historical inventory of the impact of climate change and variability on land use in an area of small-scale land users in the developing world and is an important step towards being able to predict and develop scenarios of future effects of local climate change.

The following questions were put forward:

- How has the climate (rainfall, temperature, and wind) varied during 1950-2000 (e.g. trends, extremes)?
- How has the land use changed during the past 50 years?
- To what extent is the change in land use climate driven?
- How has land users dealt with the climatic variability in the past?

As a consequence of the findings during these two years, the questions could be modified to:

- How has rainfall and temperature varied during 1950-2000 (e.g. trends)?
- How has the land use changed during the past 25 years?
- To what extent is the change in land use climate driven?
- What other factors are affecting land-use change?
- How has land users dealt with the climatic variability and change in the past?
- What will the regional climate be in the future?

2. METHODOLOGY AND DATA
2.1. Multidisciplinary approach

From the research questions and objectives defined it is obvious that the approach of the project requires integrated research involving a number of disciplines. Many research projects are termed multidisciplinary without a clear definition. A useful strategy is to distinguish multidisciplinarity from interdisciplinarity as well as transdisciplinarity. A multidisciplinary research project crosses borders between different disciplines, but with a firm respect for the continued existence of these borders. In an interdisciplinary research project, the importance of the borders between the participating disciplines is diminished or even vanished. It can be hard to trace theories, methods and results to separate disciplines. In a transdisciplinary research project knowledge integration is not provided by disciplinary structures. Rather transdisciplinary knowledge production is beyond disciplines and involves different parts of society (Gibbons et al. 1994; Klein 1996; Egneus et al. 2000).

According to this definition, the present research project is multidisciplinary, but with some important elements of interdisciplinarity. The human composition of the project is clearly linked to disciplinary expertise (land use, climate impact research, socio-economic aspects, resources and environment science etc.). Further, the organization of the project is also multidisciplinary with representatives of different departments being responsible for parts of the project corresponding to their disciplinary expertise. However, the importance of disciplinary borders between the collaborating partners has been somewhat diminished through a common aim and a common set of research questions. This has been particularly evident in the methodology applied by the project. Analysis of climate data has been directly linked to land-use data, as well as quantitative and qualitative results from questionnaires, individual interviews, group discussions and participatory exercises. The precondition for such an approach has been joint fieldwork where partners from different disciplines have worked together. Another interdisciplinary element of the project has been the writing and presentation of joint papers. The themes of the two published papers (Knutsson et al. 2003, Hageback et al. 2004) originates from the common aim of the project and are interdisciplinary in the sense that results and methods that normally are confined to specific disciplines have been integrated for the purpose of a common theme or question. The multidisciplinary approach used in this study could be summarized with the conceptual framework presented in fig. 3.

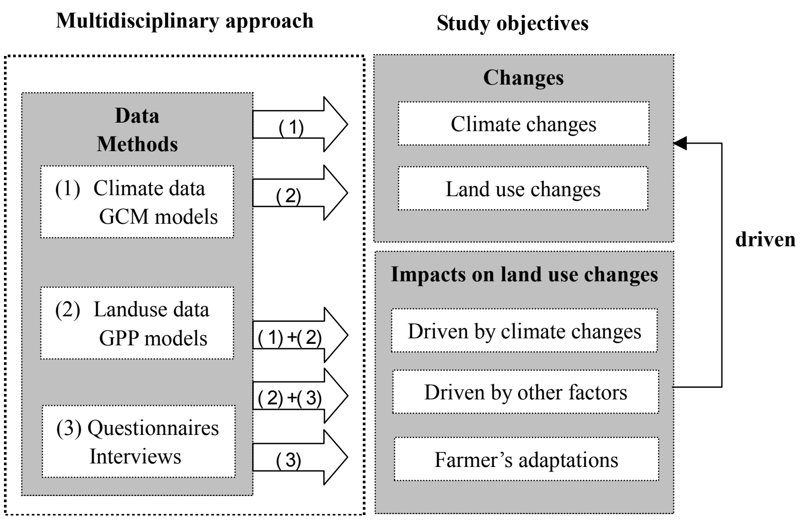


Figure 3: The conceptual framework of the multidisciplinary work.

2.2. Climate data

There are climate data of first class stations in 160 observation station in the country. Monthly mean temperature and monthly total precipitation are available. Generally the instrumental climate data begin from 1951, but several single stations such as Beijing and Shanghai have longer time series for temperature records. As far as the area for our study is concerned, a local climate station, Ansai weather station was used with daily data on temperature and precipitation. From the climate point of view, the study area is located in the area where the large scale circulation could produce the significant impact on local climate (Chen and Chen, 2002). Therefore, the climate and environment change in this area will be closely related to large scale circulation.

The local data included a small amount of missing data that was interpolated interpolated linearly in the time-dimension. Monthly and yearly means of the daily temperature and precipitation were calculated. Seasonal statistics were constructed based on the monthly data. Following the standard definition of seasons, Winter is defined as Dec-Feb, Spring as Mar-May, Summer as June-Aug and Fall as Sep-Nov (e.g. Domrös and Peng 1998).

In order to look at the future climate change, present and future climate simulations by General Circulation Model (GCM) have been used. By using data from the two GCM-models, ECHAM4 and HadCM3, future scenarios of the general climate in Shaanxi were produced. To achieve this, data was received from the IPCC data distribution centre (http://ipcc-ddc.cru.uea.ac.uk/) on 8 July 2003 and one grid was chosen covering the Shaanxi Province and the weather station in Ansai (109°30'E, 36°34'N). For ECHAM4 the coordinates of the grid closest to Ansai are 109.7E, 37.7N and for HadCM3 the grid coordinates are 108.7E, 37.5N. For each model three runs where selected, i.e. a control run for present climate and two future scenarios based on IPCC A2 and B2 Emission Scenarios, referred to as SRES (IPCC 2000). The A2 is characterised by a very rapid increase in population, mostly regional economic growth and relatively slow implementation of new technology. The B2 scenario is mainly focused on sustainable development of economy as well as social and environmental issues on a local scale. The GCM-runs refer to different time-periods with ECHAM4 covering the following periods: control run 1860-2099, A2 and B2 1990-2100, and HadCM3: control run 1858-2097, A2 and B2 1950-2099. The climate is presented using monthly values of temperature and precipitation at 2 meter level.

By comparing observational data from Ansai with modelled data during 30 years, 1970-2001, it was possible to evaluate how well observations and model output agrees for the Shaanxi Province. The future climate changes for the area was calculated by using the difference between each scenario run and the control run, i.e. A2 run – control run, and B2 run – control run.

2.3. Land-use data and estimation of primary production

The first source of information about land use is obtained by interviewing local farmers. During field work in the villages key-informant interviews and group discussions were conducted. While the main purpose of the interviews was getting the land-use history of the village, the group interview focused on climate variations in the past, following Bernard (1995) and Berg (1998). An interactive tool, the "climate game" (see fig. 8 under Interview data), was used to have the groups interactively discuss the climate during the last 40 years, divided into four 10-year periods starting in 1962 to 2002 (Bernard 1995; Berg 1998; Knutsson et al. 2003; Hageback et al. 2004). The main part of the data was collected in Danangou Watershed but three adjacent villages were also part of the study.

From Ansai County Statistical Bureau and Land Use Office data was collected on population and land use from the years 1996-2001, since no later data had been published at the time of data collection (April, 2003). The validity in Chinese statistical data has been discussed in earlier research (Rawski and Xiao 2001) due to the rapid changes and the control over government documents with tendencies of biases, while other studies use the data without further ado (Skinner et al. 2001). The issue of validity of statistical data has been considered here and no result is solely based thereon.

To examine the large scale land-use change and hence vegetation change, three Moderate-Resolution Imaging Spectroradiometer (MODIS) Terra vegetation indices (VI) from 19-27 of August 2000, 13-28 August 2001 and 13-28 of August 2002 was used with a resolution of 250 m. The month of August was used due to its annual vegetation peak (Wu et al. 2003).

The MODIS VI is a (app.) 16-day compositing data set where as many as 64 observations are used from the period to retain the highest quality data, i.e. cloud free, nadir-view pixels and a minimal residual atmospheric aerosol. MODIS VI consists of two vegetation indices; Normalized Difference Vegetation Index (NDVI) and MODIS Enhanced Vegetation Index (EVI). The NDVI is a normalized ratio of the near infra-red (NIR) and red bands,

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{red}}{\mathrm{NIR} + \mathrm{red}} \qquad (1)$$

The NDVI is often used as an index to reveal seasonal and/or inter-annual changes in vegetation cover. Its disadvantages are the nonlinearity of ratio-based indices and the influence of noise effects from the atmosphere. EVI offers improvements over the traditionally used NDVI by reducing saturation at high vegetation cover and reducing soil background effects (Justice et al. 2002) and has shown good performance for biophysical measurements based on field observations (Huete et al. 2002). The EVI was developed to optimize the vegetation signal with improved sensitivity in high biomass regions and to improve monitoring through de-coupling of the canopy background signal and a reduction in atmosphere influences. The index is written as,

$$\mathrm{EVI} = G\frac{\rho\,\mathrm{NIR} - \rho\,\mathrm{red}}{\rho\,\mathrm{NIR} + C_1 \times \rho\,\mathrm{red} - C_2 \times \rho\,\mathrm{blue} + L} \qquad (2)$$

where ρ are atmospherically corrected or partially atmosphere corrected (Rayleigh and ozone absorption) surface reflectance, L is the canopy background adjustment that addresses nonlinear, differential NIR and red radiant transfer through a canopy, C_1, C_2 are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band. The coefficients adopted in the EVI algorithm are, L=1, C_1 = 6, C_2 = 7.5 and G (gain factor) = 2.5 (Huete et al. 2002). Due to the characteristics of the two indices, they complement each other in vegetation change analyses.

The use of high resolution data over fragmented land covers can be problematic if small features are of relevance since they usually gives decreased areal extent; a problem that can be approached by incorporating finer resolution images and ground surveys (Hlavka and Dungan 2002). However, in this study the MODIS images were used to study changes in regional vegetation for which the resolution of the data is suitable (Justice et al. 2002). The images were preprocessed to highest degree (level 3) by the producer (http://modis.gsfc.nasa.gov/data/dataproducts). Geometric correction was done with RMS values below pixel size (Ostwald 2004).

Vegetation cover is closely related to biomass production. The biomass production of the semi-arid environments of northern China is directly related to variation and change of precipitation and temperature. This is especially true during years of drought as it directly affects millions of households dependent on agriculture and livestock. According to IPCC (IPCC, 2001) higher variability in summer precipitation and increasing temperatures is likely to strike the central parts of Asia. The magnitude of the potential impact of global change on biological production, including the temporal and spatial patterns, is however still inadequately examined.

The aim of the next section of the project is to investigate how projected regional climate change scenarios could impact the biological production in the Ansai region (fig. 4) as estimated with a satellite based light use efficiency (LUE) model. The applied light use model is partly remote-sensing driven; hence the analysis is as a sensitivity analysis of the model to GCM predicted precipitation and temperature changes as the NDVI itself captures the actual situation for the period 1982 to 1999. The aim was achieved through the following main working steps

a) Compute Gross Primary Production over one 8 x 8 km pixel centered over the Ansai area for the period 1982-1999 based on existing data.
b) Extracting precipitation and temperature data over the area for one GCM scenario, in this case the ECHAM4 – Scenario A2 data set, for the period 2051 to 2068, in other words a climatic scenario about 50 year from now.
c) Run the model again first with the original data, then with the adjusted temperature series, and, in a third run, also including the adjusted precipitation series.
d) Compare the outcome of the primary production runs as well as some of the intermediate steps of the model runs.

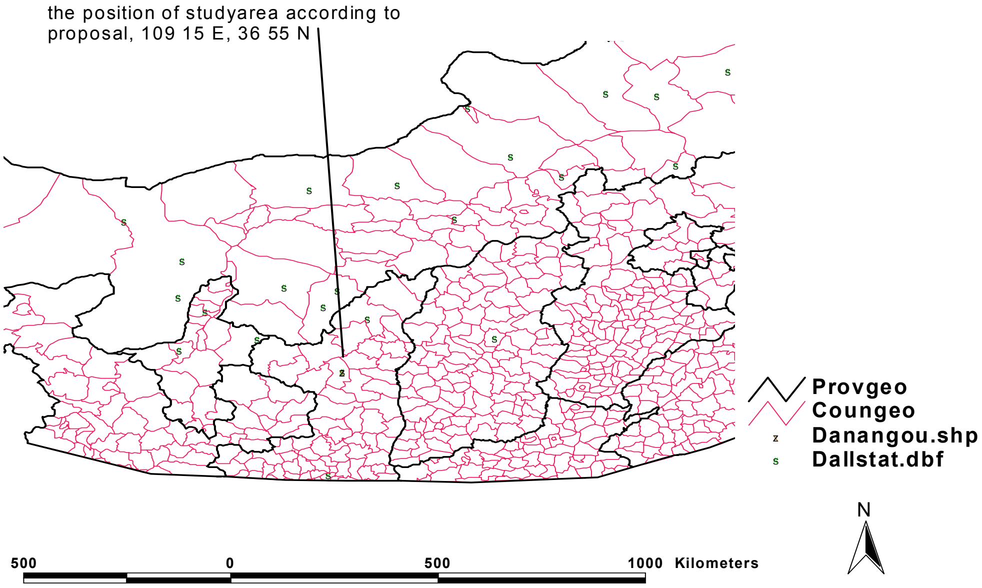


Figure 4: Study area of Ansai.

The Seaquist-Olsson model (Seaquist 2001; Seaquist et al. 2003) is a light use efficiency model using the NOAA NASA 8 km Pathfinder Land Data Set (PAL) together with climate and soil information to map the growing season GPP originally developed for the West African Sahel. The LUE approach (Monteith, 1972; 1977) proposes that biological production is directly proportional to the amount of photosynthetically active radiation absorbed by the vegetation canopy (APAR). APAR itself is the product of incident photosynthetically active radiation (PAR) between 0.4 and 0.7 μm and the reflectance properties expressed through a vegetation index i.e. the NDVI.

In the applied model PAR at the ground is computed by using top of the atmosphere reduced to ground revived PAR radiation calibrated to north China conditions through the three cloud classes from PAL´s Clouds from AVHRR (CLAVR) with ground-measured data (Runnström et al. 2003). In the hydrological component of the model, potential evaporation (PET) is partitioned into potential soil evaporation and potential transpiration through an estimation of vegetation fraction derived from NDVI. Evaporation from bare soil and potential transpiration are treated separately by a two-layer bucket model that gives an estimate of the impact of soil water stress on plant growth, where the ratio between actual to potential transpiration then yields the water stress term. The model resembles some of other LUE models to the extent that it is embedded in the LU framework. At a more detailed level the approach is unique as it considers only the water used by plants (actual transpiration) to index water stress, an approach assumed to be more biophysically realistic, and enhance the precision in the water stress term, especially across vegetation gradients. This parameterization is particularly important for applications to partially vegetated landscapes where the fate of precipitation is to a great extent controlled by relative amounts of vegetation.

The model was tested for sensitivity of input parameter errors, for the parameters NDVI, PAR, water stress and εp through Monte Carlo simulations (Seaquist 2001). As a general rule the higher the GPP the more robust the production is. Among estimated terms PAR lends the least error, the NDVI term error was relatively low determining the GPP of savannah and cropland mosaic, but contributes to over 90 per cent of the total error variance in the desert fringe. εp rarely exceeds 30 per cent of the error variance, while the model is most sensitive to the water stress scalar.

Since the original model was developed for the African Sahel it has been partly improved and adjusted to the continental type of climate prevailing in northern China and to run the model in longer time series (Brogaard et al. 2004). These changes, together with a description of input data, are presented in the following section and highlighted in grey boxes in fig. 5.

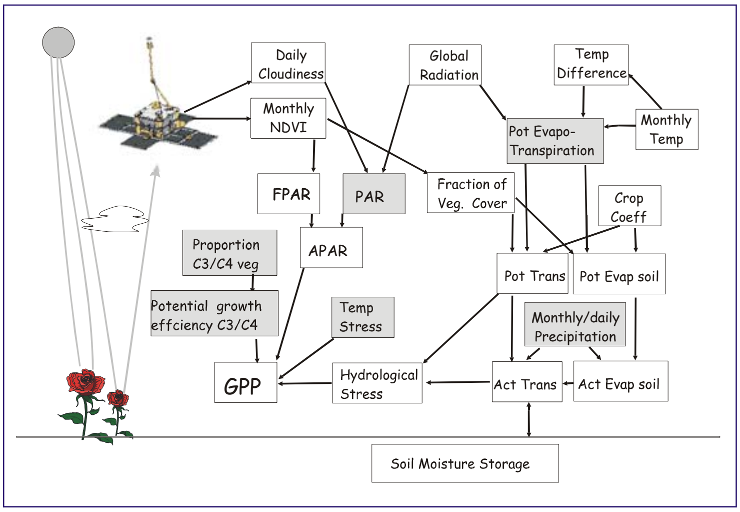


Figure 5: Overview of the primary production model.

The satellite data come from the Pathfinder Land (PAL) data set, a product derived from the NOAA AVHRR sensors (James and Kalluri 1994). NDVI at monthly intervals and daily classifications of cloud cover from the CLouds AVHRR (CLAVR) at a spatial resolution of 8 x 8 km, were used for the period 1982 to 1999. Climate data from the Ansai meteorological station, monthly mean temperature and daily precipitation observations, together with interpolated monthly mean, maximum and minimum temperatures from 40 stations covering Northern China, were used to drive the hydrological component of the LUE model. Also the temperature stress factor, partitioning of vegetation into C3 and C4 pathways, as well as the computation of C3 photosynthetic efficiency values are based on temperature input. Daily data from two stations (e.g. solar radiation, sunshine hours, and precipitation) were used for calibration purposes of the PAR component. Maximum soil moisture storage (SM_{max} – computed from topsoil texture and soil depth) was taken from version 3.5 of the FAO Digital Soil Map of the World (DSMW, version 3.5 1995).

To drive the climate sensitivity runs data ECHAM4 Scenario A2 was used. The ECHAM4 Scenario A2 was chosen as it provides a scenario with rather high temperature increases compared to the control data, particularly for the summer season (fig. 6). The parameters used were daily precipitation amounts – the same value for each day in a month, and monthly mean temperature values. The scenarios are available from 1999 to 2099, while in this study an 18 year period, 2051 to 2068, was chosen as input to the GPP sensitivity computations. This means that the scenario corresponds to a time-period beginning about 50 years from now. Temperature differences and minimum and maximum temperatures were not available, and hence for some parameters the original interpolated data set developed for a previous study covering Inner Mongolia and surroundings was used (se below).

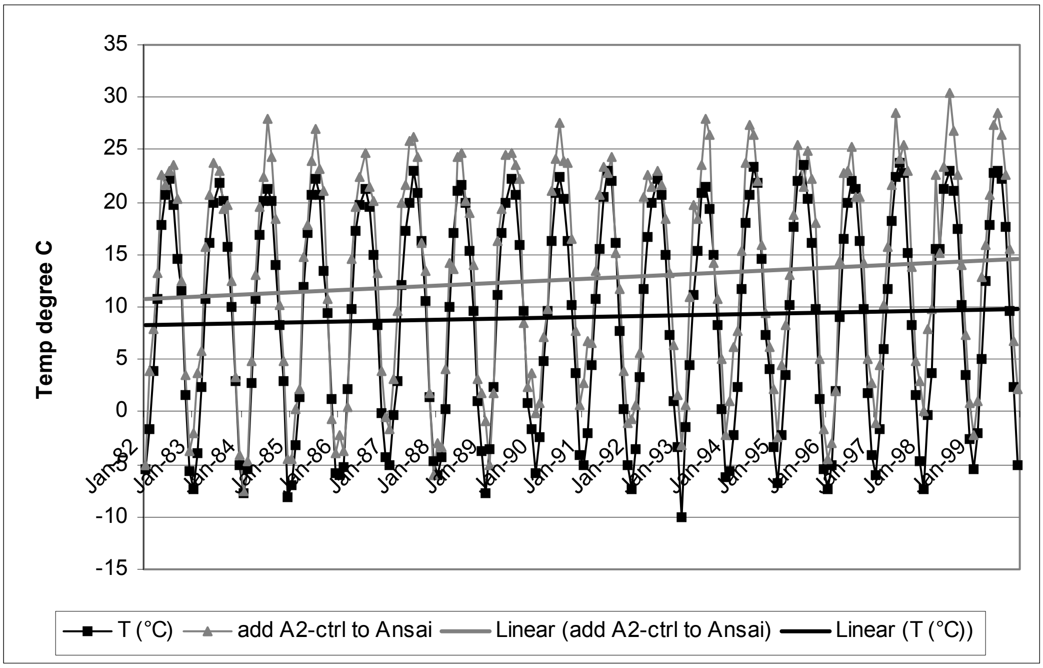


Figure 6: The original monthly temperature data and the scenario data 2051-2068.

The location of the area in the GOODE projection used in the NOAA NASA 8 km PAL data set was computed so that the climate parameter for Ansai included in the model could be used at the right location and so that parameters already at hand, such as the soil background adjusted NDVI could be extracted for time series. A program was then written to produce a grid file for all temperature and precipitation point data for Ansai in order to use the original FORTRAN programs produced for grid files 125 x 125 pixels also in this study.

The program was run to produce 128 monthly grid files (18 years) for mean temperature, for both the original and the scenario runs, as well as 6574 daily grid files for precipitation for each model run.

To compute the Hargreaves potential evapotranspiration for the pixel the temperature difference from the original data set was used. The next step was to compute fraction of vegetation cover from NDVI and two coefficients and the potential evaporation is computed for soil and vegetation separately based on this fraction. The Ritchie model (Ritchie 1972) for computation of actual evaporation from bare soil needs daily time steps and for the temperature data only at hand for monthly intervals, the same value was used for each day in the month. The bucket model, also in daily time steps, is then run to compute actual transpiration for the vegetation fraction of the pixel. The water stress value was hereafter computed trough dividing potential by actual transpiration (the latter first summed into monthly values). The temperature stress was also computed based on the original Ansai data as well as the temperature scenario.

For both the crops C3/C4 as well as C3 efficiency values the original figures computed for northern China were kept. This was done as the difference between maximum and minimum temperatures was not valuable either in the Ansai original data set or for the temperature scenarios. In this way we can also interpret any changes in the GPP computations as to origin from either changes in temperature or hydrological stress. The absorbed photosynthetic active radiation, APAR, is based on PAR and NDVI and hence is kept as in the original model runs for northern China. Based on the previous steps, GPP is computed.

To obtain the new temperature series the difference between the grid cell scenario (109.7E, 37.7N) and the control data for the period 2051-2068 was added to the original Ansai data 1982-1999.

For the precipitation data the situation was more complicated as the same procedure above often yielded negative rainfall values when adding to the original Ansai data. Therefore, a simplification of the scenario was done by computing the average monthly difference between control and grid-cell value for the 18 year period and adding this to the original data. Hence the same annual change pattern was added to the original rainfall data for Ansai each year (fig.7).

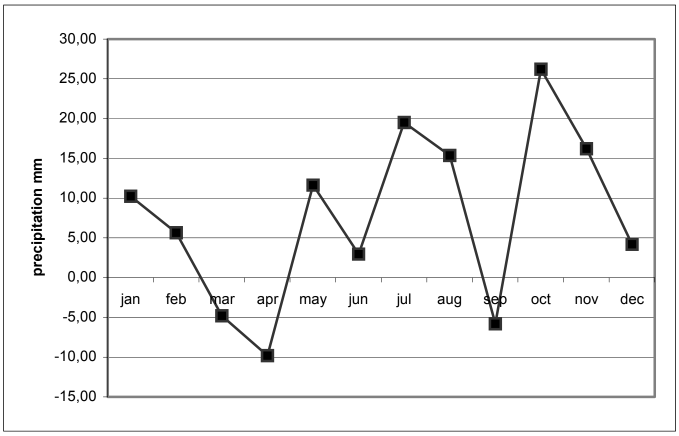


Figure 7: The monthly values that have been added to the original Ansai precipitation data each year to create precipitation scenario.

2.4. Interview data

In order to adapt the way of interviewing to the different aspects of the research questions, and to test information obtained through one specific form of interviewing with another form, a wide range of interview methods have been employed during two fieldwork periods. The first lasted for six weeks in April and May 2002 and the second for two weeks in April 2003. During the first fieldwork period Jenny Hageback and Jenny Sundberg conducted a Minor Field Study on *Climate variations in relation to local land use and farmers' perception of climate* (Hageback and Sundberg 2002). Before, during and after their fieldwork, they were guided by four project researchers (Deliang Chen, Madelene Ostwald, Per Knutsson, Yun Xie). The study entailed (1) informal interviews with the purpose of becoming familiar with the area and the local government system; (2) a total of 10 unstructured and semi-structured interviews on the history of the village, agricultural and climatic calendars, the local government system, education, subsidies of the Cropland Conversion Programme, and the land tenure system; (3) a total of 38 structured interviews (27 male and 11 female) were conducted in the form of a questionnaire. The main topics of the questionnaire were household background information, crops, weather, rainfall, disasters, the future of the two villages; (4) two unstructured group interviews were held with a female and male group in Danangou, with the intention to ensure the active participation of the two groups by opening up for discussions about opportunities and limitations in farmers' livelihoods. By allowing farmers to influence the topics of the discussion, it was possible to test the extent to which land-use changes were driven by climate change; (5) Four semi-structured group interviews were held with one male and one female group in Leipingta and Danangou respectively. These interviews were structured around a participatory ranking exercise the "climate game" (Hageback and Sundberg 2002), where the groups were asked to estimate four climatic variables: temperature, rainfall, wind and snow, on a timeline from 1962 – 2002 (fig.8).

Figure 8: Semi-structured group discussion working with the "climate game", Danangou catchment May 2002.

The interviews during the second fieldwork period focused on household economy. The objective of this study was to obtain information about the strategies of the households following the implementation of the Cropland Conversion Programme. The method employed can be described as a combination between a questionnaire and semi-structured interviews, where not only detailed quantitative information on household income and costs, and land use for 2002 were asked for, but also more qualitative information concerning causes and effects of different sources of income and costs and the impact of the Cropland Conversion Programme. A sample of 22 households was covered by the interviews (12 from Danangou and 10 from Leipingta).

A problem attached with all forms of interviewing has been the selection of respondents. With limited local knowledge, we have been forced to depend on a key informant in order to fulfil our demands for strategic or representative selections. The key informant through both fieldwork periods has been the former president in Danangou village. He is a retired man who is respected by most households in both villages. During the initial stages of the first fieldwork period, we feared that the former village president would influence the selection of respondents and maybe even their answers. However, during fieldwork we have learned that the former village president has rather acted as a guarantee for reliable information during the interviews. Through the endorsement of the former village president, most respondents have felt secure enough to answer our questions truthfully. On several occasions, the former village president has pointed out errors in the information obtained through interviews and when we have checked these errors independently by other sources, they have been confirmed. However, the risk that our selections of respondents have been biased is still there, at least to a limited extent.

2.5. Limitations and changes of the data and methods

The climate variables that have been used in the analyses were precipitation and temperature, while wind is neglected due its limited relevance to the objectives and research questions.

For land use and vegetation analyses focus has been on satellite imagery of different resolutions, while aerial photography was not used due to lack of availability.

One of the limitations that were discovered during the first visit to that area was the time scale. To get information about the past we had to rely on data from the farmers and their ability to recollect back in time. It showed that due to the local setting of fairly recent agricultural settlement in the area and reliability of memory, important time land marks had to be used. Here the introduction of Household Responsibility System in 1982 was one such time land mark. Therefore the time-frame given in the objectives and questions of the research is changed from 1950 to 2000 to mainly focus on 1980 to 2003.

2.6. Related research

The impact of climate change on agriculture has been part of a national key project (1996-2000) entitled "Studies on short-term climate predictions system in China". This project looked at strategies for reducing the impact of climate disasters on agriculture (National Climate Centre 2000). Ansai County has a soil and water conservation station that belongs to a network consisting 11 monitoring stations sponsored by the Chinese Government (Liu 1999). Another related project was supported by European Union and focused on the Danangou watershed area (Erochina 2000/2001). The aim of the project was to develop alternative land use and soil water conservation strategies to increase sustainability by reducing soil and water losses. Studies with focus on socio-economical aspects (Carlsson 2000; Chen et al. 2001; Rosmuller 1999) as well as on soil conditions (Fu et al. 2000; Qui et al. 2001, Wang et al. 2001) have been conducted.

3. RESULTS AND DISCUSSIONS

3.1. Climate

3.1.1. Regional and local climate variability

The regional and local climates have varied great during the measurement period. In terms of long term linear trend on the regional level, the northern part of Shaanxi Province has experienced a 19% decrease (1.8 mm/year) of yearly rainfall from 1951 to 1999. In Ansai the rainfall has decreased 14% (2.6 mm/year) during 1970-2000, while the temperature has increased almost 1°C over the same period (table 1) (Hageback et al. 2004). The table also shows that 58% of the precipitation falls during summer, when the monsoon arrives. A decreasing trend of the rainfall can be seen in all season except spring. The trend is not significant as indicated by the very low correlation coefficients. This is due to the very large interannual variability in the area.

Table 1: Statistics and trends of Ansai precipitation and temperature 1970-2001.

Precipitation	***Yearly***	***Spring***	***Summer***	***Fall***	***Winter***
Mean (mm)	579	92.1	333	139	15.9
% of yearly total		16%	58%	24%	2.8%
Std (mm)	129	44.7	105	66.0	13.6
Trend (mm/year)	-2.6	0.3	-1.1	-1.5	-0.4
Correlation coefficient	-0.2	0.1	-0.1	-0.2	-0.3
Total change calculated from the trend[1] (mm/32 years and %)	-82 -14%	10 11%	-35 -10%	-47 -34%	-12 -78%
Temperature					
Mean (°C)	8.97	10.51	21.49	8.71	-4.81
Std (°C)	0.60	0.87	0.71	0.77	1.22
Trend (°C/year)	0.03	0.02	0.01	0.03	0.06
Correlation coefficient	0.48**	0.23	0.21	0.39*	0.47**
Total change calculated from the trend[1] (°C/32 years)	1.0	0.6	0.3	1.0	1.9

* P <0.05, ** P <0.01 Student's t-test. N=32. [1]

Looking at local and regional level with regards to the precipitation, which showed a great variability on the local level, it is possible to see that the regional trend is similar to that of the local scale (fig. 9).

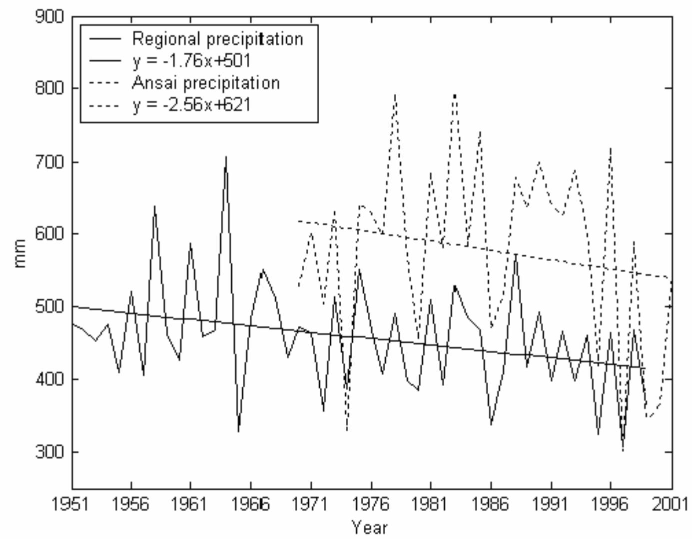


Figure 9: Comparison of trends local precipitation in Ansai and trend in regional precipitation in the Shaanxi Province. The trend analysis is done by linear regression with the yearly means.

3.1.2. Climate change simulated by two GCMs

A general description of the climate as well as the similarities and differences in GCM-model output for Shaanxi are presented in fig. 10-13. In fig. 10 and 11 the annual temperature cycle are shown with a temperature maximum during July for both models and all runs as well as a temperature minimum during January.

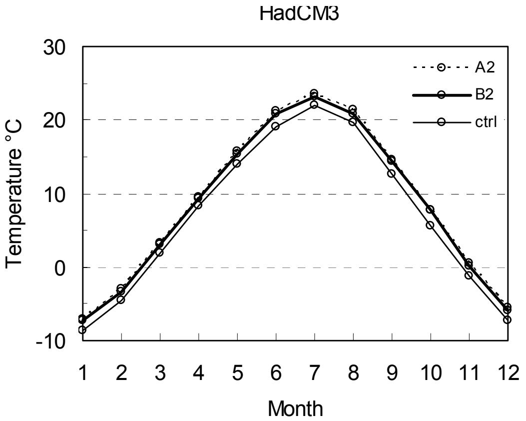


Figure 10: Simulated average temperature monthly values from HadCM3 during the period 1950-2099. The red line represents the run using emission scenario A2, blue line represents the run using emission scenario B2 and the green line is the control run.

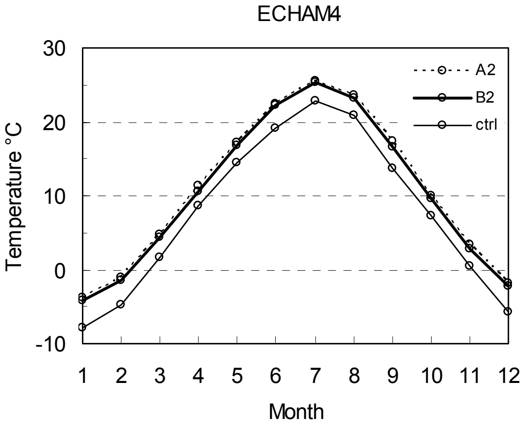


Figure 11: Simulated average temperature monthly values from ECHAM4 during the period 1990-2100. The red line represents the run using emission scenario A2, blue line represents the run using emission scenario B2 and the green line is the control run.

The precipitation in Shaanxi during a year is characterised by a dry winter and a wet summer monsoon with the highest precipitation rates falling in August. A difference between the HadCM3 and ECHAM4 is seen as the ECHAM4 model simulates a more pronounced two peak pattern of precipitation, one in May and the other in August. The HadCM3 does not show this pattern. Instead it presents a yearly cycle with high values of precipitation during the whole summer period as well as the spring month May and the autumn month September. This is clearly seen in the A2 and B2 runs (fig. 12 and 13).

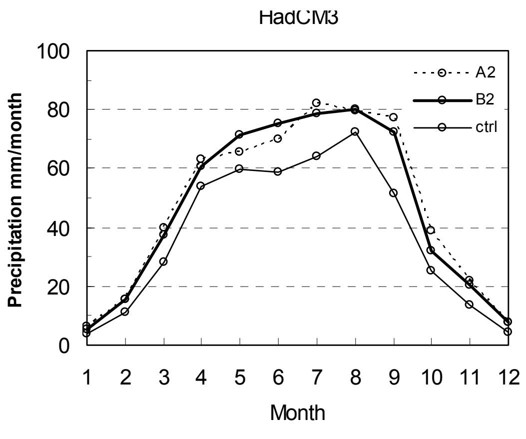


Figure 12: Simulated average precipitation monthly values from HadCM3 during the period 1950-2099. The red line represents the run using emission scenario A2, blue line represents the run using emission scenario B2 and the green line is the control run.

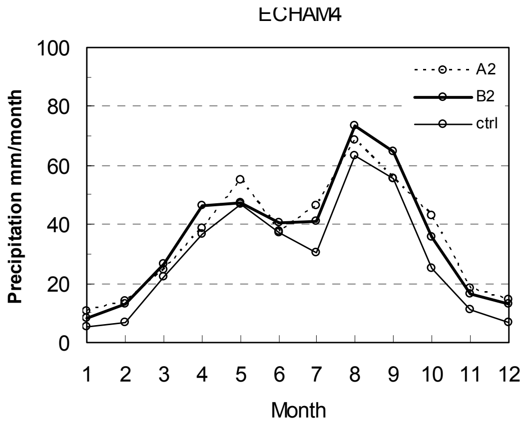


Figure 13: Simulated average precipitation monthly values from ECHAM4 during the period 1990-2100. The red line represents the run using emission scenario A2, blue line represents the run using emission scenario B2 and the green line is the control run.

By calculating the difference between scenario A2 and the mean of the control run, as well as scenario B2 and the mean of the control run, scenarios of a future temperature-change in the Shaanxi Province are presented (fig. 14). A difference between models and scenario runs is present with generally higher temperature changes using A2 scenarios than B2. Also it can be seen that HadCM3 generally show smaller changes than ECHAM4. Compared with the climate conditions of today the temperature may increase 1-2,5 ºC during the next 50-year period and 3-6 ºC during the next 100-year period.

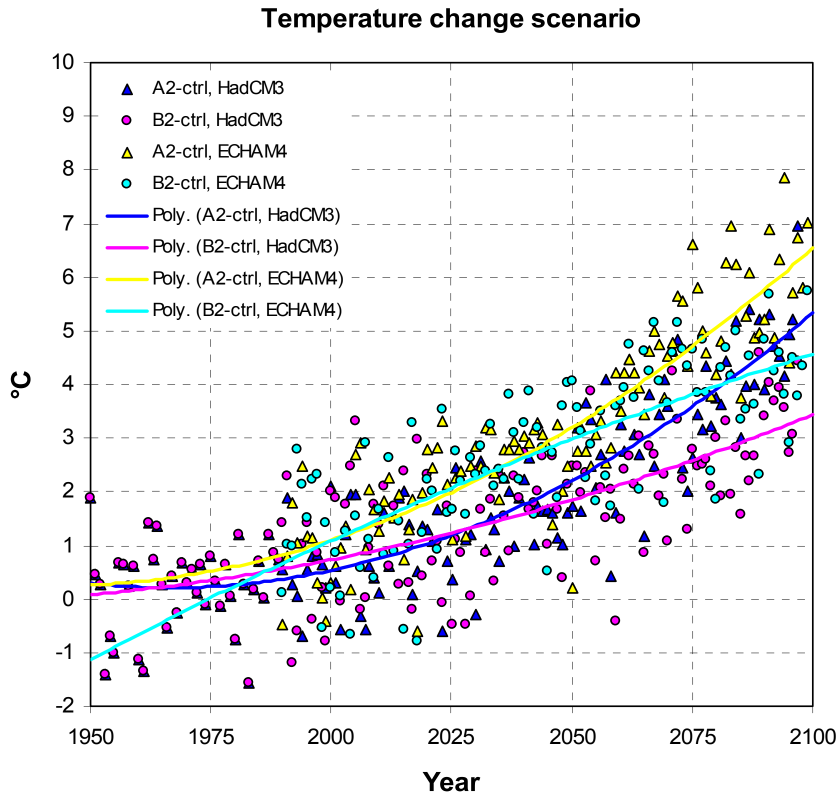


Figure 14: Shaanxi / Ansai GCM-grid with simulated temperature change by year presented as difference from control scenario.

Polynomial regression line has been calculated for the two models and the two scenarios A2 and B2 respectively with the resulting temperature equations below. For equations calculated using HadCM3 values N=148, and for ECHAM4 N=150.

A2-ctrl, HadCM3: $y = 0.0003x^2 - 1.1325x + 1113.8$
B2-ctrl, HadCM3: $y = 9E\text{-}05x^2 - 0.3569x + 339.89$
A2-ctrl, ECHAM4: $y = 0.0003x^2 - 0.9735x + 945.17$
B2-ctrl, ECHAM4: $y = -6E\text{-}05x^2 + 0.2884x - 328.32$

The correlations are generally very strong and an increase in temperature is seen in all models and scenarios. A correlation coefficient with a significance level of 0,01 is found (according to Pearson product-moment correlation coefficient), see table 2.

Table 2: Coefficient of determination, correlation coefficient and significance level of the modelled temperature trends in the Shaanxi Province.

Model run	**R^2**	**R**	**Significance level**
A2-ctrl, HadCM3	0,76	0,87	0,01
B2-ctrl, HadCM3	0,53	0,73	0,01
A2-ctrl, ECHAM4	0,79	0,89	0,01
B2-ctrl, ECHAM4	0,57	0,76	0,01

By calculating the difference between scenarios and the mean of the control run, similar to the temperature presented in fig. 14, scenarios of changes in precipitation in the Shaanxi Province are presented, fig. 15. Differences in the rate of change between the models are present but no significant differences between the A2 and B2 scenarios are seen. Another difference from the temperature change scenario is that HadCM3 is now the model giving the highest rate of precipitation change compared to ECHAM4.

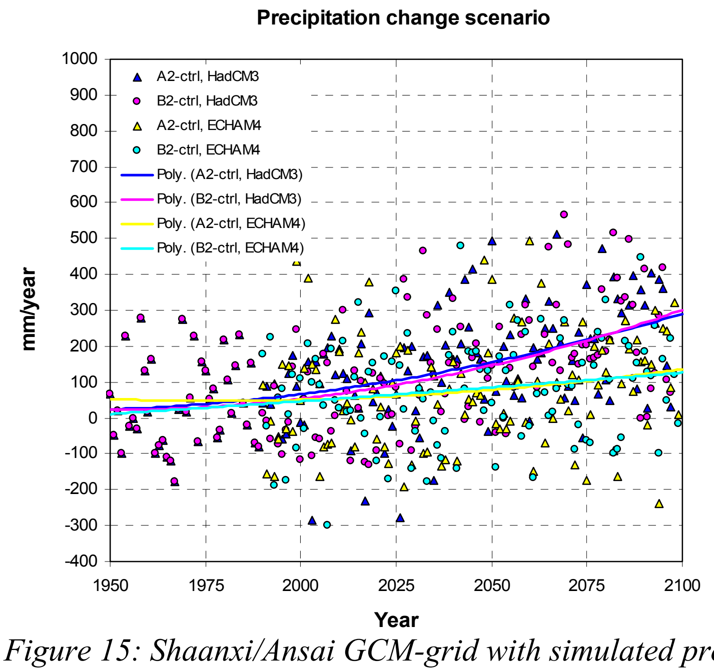


Figure 15: Shaanxi/Ansai GCM-grid with simulated precipitation change by year presented as difference from control scenario.

The trend in precipitation is calculated using a polynomial regression and has been calculated for the two models and the two scenarios A2 and B2 respectively. For equations calculated using HadCM3 values N=148, and for ECHAM4 N=150.

A2-ctrl, HadCM3: $y = 0.0092x^2 - 35.379x + 34129$
B2-ctrl, HadCM3: $y = 0.0123x^2 - 48.049x + 46860$

A2-ctrl, ECHAM4: $y = 0.0059x^2 - 23.372x + 23167$
B2-ctrl, ECHAM4: $y = 0.0005x^2 - 1.3112x + 614.58$

The precipitation shows an increasing trend with fairly high correlations with significance levels of 0,1 – 0,01, see table 3. Though, the correlation is not that strong as for the temperature, especially for the output of ECHAM4.

Table 3: Coefficient of determination, correlation coefficient and significance level of the modelled precipitation trends in the Shaanxi Province.

Model run	R^2	**R**	**Significance level**
A2-ctrl, HadCM3	0,25	0,50	0,01
B2-ctrl, HadCM3	0,27	0,52	0,01
A2-ctrl, ECHAM4	0,027	0,16	0,05
B2-ctrl, ECHAM4	0,031	0,18	0,10

The seasonal cycle has a strong influence on the climate in the Shaanxi Province with dry and cold winters and warm and wet summer months. It may therefore be interesting to analyse the future changes in temperature and precipitation for each month separately. Fig. 16 presents the HadCM3 scenarios of A2 and B2 for temperature during one month in each season. Winter is represented by January, Spring by April, Summer by July and Autumn by October. All the seasons have a similar increase in the temperature trend with approximately 5 ºC at year 2100.

Fig. 17 presents the HadCM3 scenarios for precipitation. Here, the difference is larger both in the trend and in variance. Winter does not show a significant change, but at the same time the precipitation and its variability is very low. The highest increase in precipitation occurs during the summer. When comparing all summer months as well as May and September it is found that the highest change in precipitation will, according to the simulation, occur in July. HadCM3 does simulate the precipitation differently than ECHAM4 as seen in fig. 12 and 13. However, due to the great impact of the summer monsoon on the water situation in the area, it is important to note that HadCM3 indicate a change in the onset as well as duration of the summer monsoon.

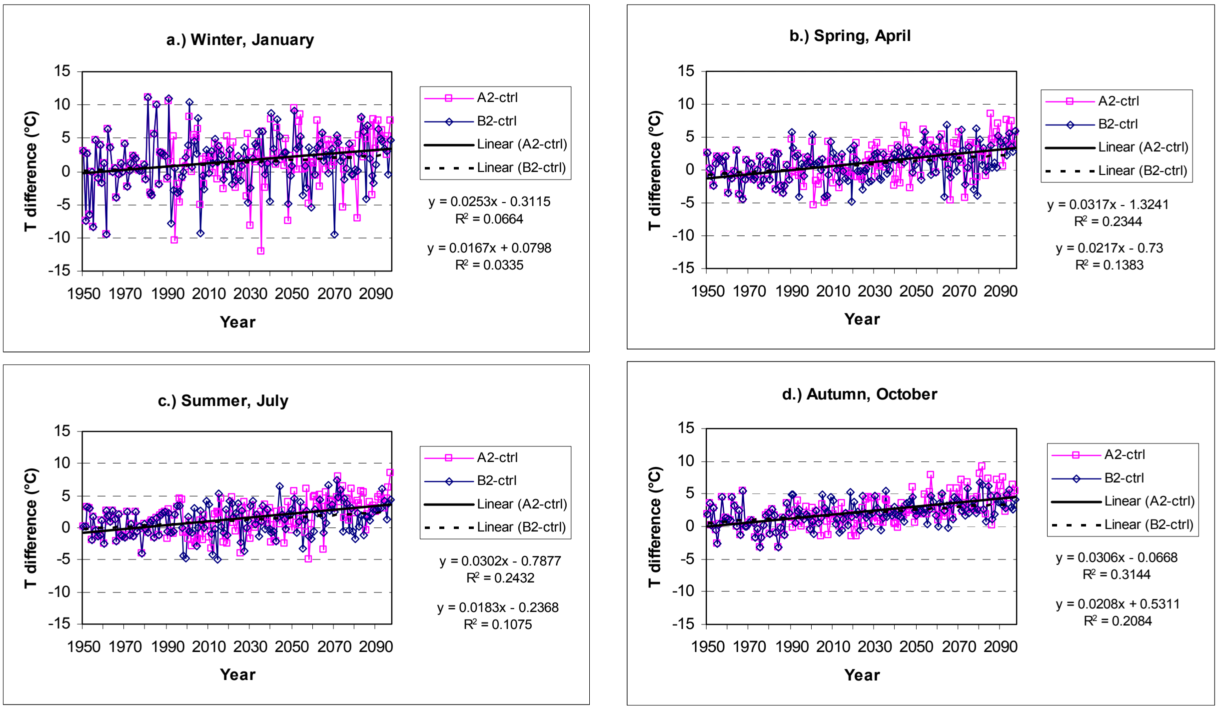


Figure 16: The figure presents HadCM3 temperature seasonal scenarios of A2 and B2. Each season is represented by one month where a.)Winter is characterised by January, b.) Spring by April, c.) Summer by July and d.) Autumn by October. N=148.

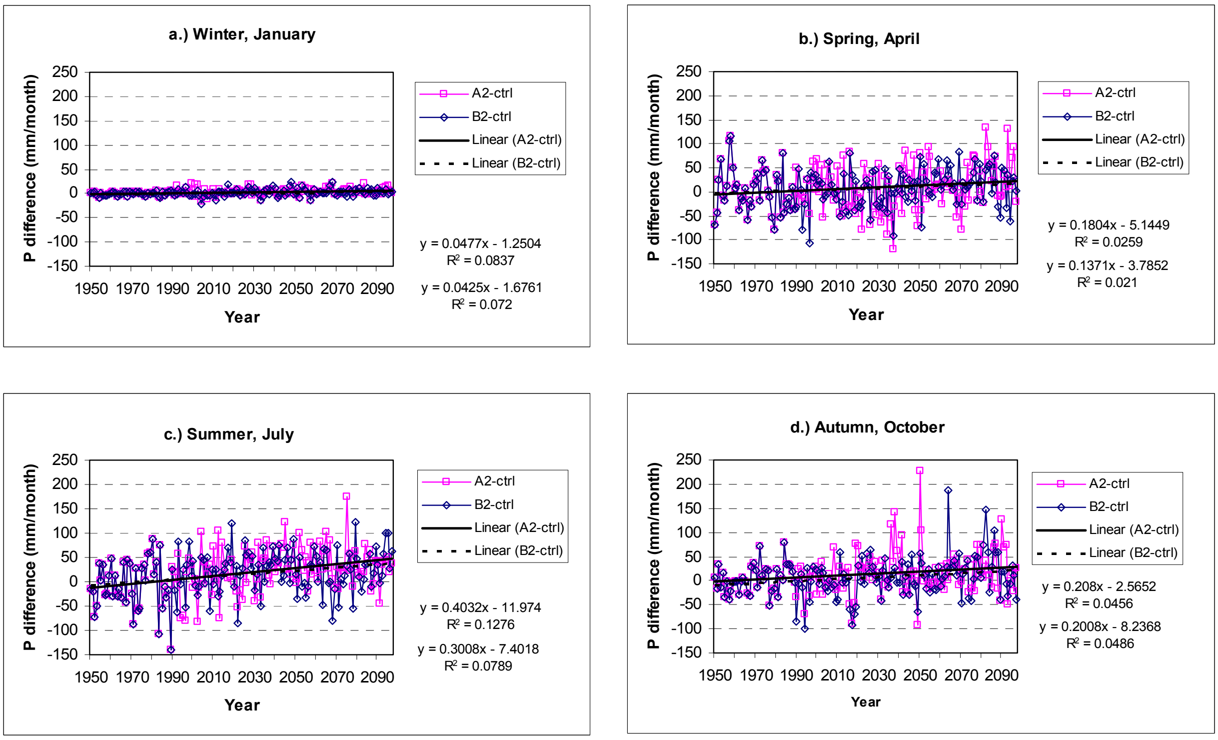
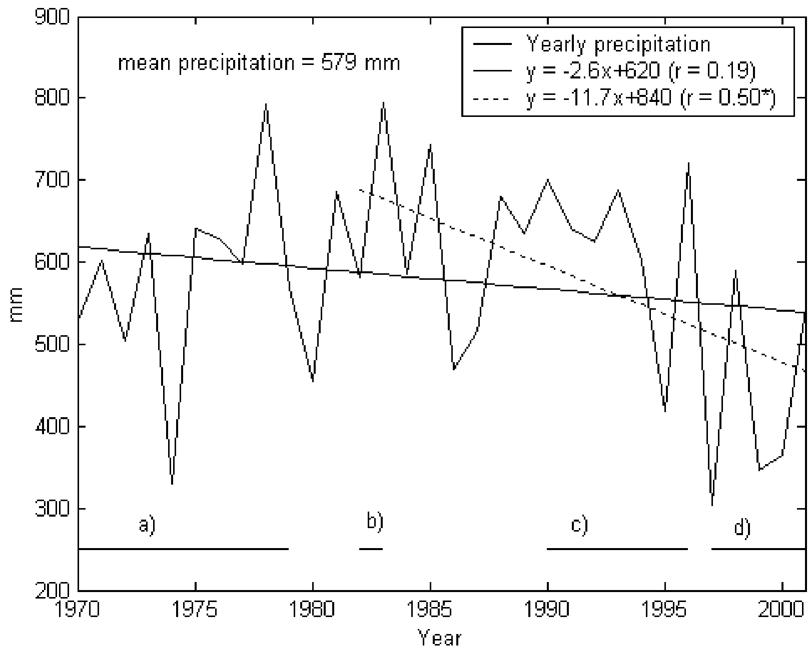


Figure 17: The figure presents HadCM3 precipitation seasonal scenarios of A2 and B2. Each season is represented by one month where a.) Winter is characterised by January, b.) Spring by April, c.) Summer by July and d.) Autumn by October. N=148.

3.2. Land use

3.2.1. Land-use changes in relation to climate and policies

A survey of the impact of climate variability on land use leads to several observations. Fig. 18 shows a summary of the land-use changes that has occurred in Danangou watershed during the last 30 years in relation to yearly precipitation data. The land-use methods described have been the most important factors for farm-development according to the farmers themselves.



- P <0.05 Student's t-test.

Figure 18: Land-use change compared to yearly precipitation from Ansai weather station (for explanation see below)

a) In the 1970s a new method of planting was introduced. During three years in the 1970s intercropping was used. Except in 1974, this decade had more rain compared to the previous few years, according to the climate data.

b) In 1982, the period during which the Household Responsibility System was operating in the Danagou area, 18% of the farmers started with off-farm work and 26% with livestock. In 1982-83 they also started to use plastic cover on their seedlings (used by all farmers today). The years around the period were not unusually dry, hence the climate can not explain the land-use change.

c) In the 1990s another kind of plastic cover technique was introduced (used by all farmers today), at the same time a decreasing rainfall trend occurred. According to the data the last part of the decade was especially dry.

d) During the last years (1997-2002) more than half, 58%, of the farmers changed their main crop, 13 out of 15 livestock keepers stopped raising livestock and more than 40% started with off-farm work. In 2001 8% started to raise livestock. In 1999 the Cropland Conversion Program was implemented in this area, which also impacted the land use. This period has been very warm and dry, which may be the reason for more off-farm work and the change of main crop.

During large part of this period, relaxation on the household registration system (hukou) and the work unit system (danwei) affected the mobility of particularly the agrarian population in China and hence their possibility to off-farm income, which in this context is worth mentioning (Chan and Zhang, 1999; Lü and Perry, 1997). However, it is hard to link these changes as climate driven in the direct sense.

One other way to look at the changes is to examine the crops that were used in the past and what is grown today (table 4).

Table 4: Change of crop from 1980s until 2003

	Flat land	*Hillslope*
Early 1980	Corn Foxtail millet Pearl millet Tobacco Potatoes	Foxtail millet Pearl millet Buck wheat Wheat Potatoes Beans
Mid-90s	Corn Foxtail millet Pearl millet Tobacco	Foxtail millet Pearl millet Buck wheat Potatoes Beans
2003	Corn Pearl millet Potatoes Tree plantations Vegetables Green houses Tree nursery	Trees Grass

Corn and potatoes, two of the crops still grown in these villages are by no means the most drought resistant crops. On the contrary, from a ranking exercise made by farmers and a scientist (table 5), potatoes and corn are put in the more water dependant end, while foxtail millet and buck wheat are rather drought resistant, but are no longer planted in this area.

Table 5: Ranking the crop sensitivity to rainfall

Ranking*	***Prof. Li***	***Respondent 42***	***Respondent 6***
1	Buck wheat	Soybean	Corn
2	Potatoes	Buck wheat, potatoes and sorghum	Potatoes
3	Corn		Buck wheat
4	Soybean		Pearl millet
5	Pearl millet	Pearl millet	Foxtail millet
6	Foxtail millet	Foxtail millet	

*1 is most rainfall dependant and 6 is least dependant.

This means that even though the farmers are experiencing unreliable rainfall, they have chosen to grow water sensitive crops lately. This will be further discussed under the result in the Interview section.

What is obvious from table 4 is that the hillslopes are no longer used for agricultural purpose. The reason for this is the introduction of Cropland Conversion Program that was introduced 1999 (see Social and political settings). From a study conducted in three adjacent villages to Danangou Watershed, the land-use change from 1980 to 1995 and from 1995 to 2003 was conducted (table 6). In all three villages the hillslope land is no longer used for agriculture and along with that is the dependency on rainfed agriculture gone.

Table 6: Land-use change from 1980-1995 and 1995-2003 on village level.

% change	*Total land*	*Hillslope land for agriculture (orig. land)*	*Flat land*	*Rainfed (orig. land)*	*Fruit trees*
Village 1					
1980-1995	0	0 (44 ha)	0	-13 (53 ha)	0
1995-2003	0	-100	-20	-100	0
Village 2					
1980-1995	0	-59 (61 ha)	-20	-60 (69 ha)	0
1995-2003	-8	-100	-9	-100	0
Village 3					
1980-1995	0	-53 (27 ha)	-64	-100 (32 ha)	0
1995-2003	0	-100	0	0	0

When looking at the Ansai County as a whole, the official statistics are showing an increase of yard land and forest land (table 7), which is an effect of the Cropland Conversion Program. The decrease in cultivated land is rather low.

Table 7: Ansai County changes in population and cultivated area from 1995 to 2001.

(pers and ha)	*1995*	*1996*	*2000*	*2001*	*2002*	*% change 1995-2001*	*% change 1996-2002*	*% change 2000-2002*
Total area*	295000			295000		*0*		
Total pop. *	148808			152153		*+2.2*		
Agr. Pop.*	136088			137005		*0*		
Non-agr. Pop.*	12720			15148		*+19.1*		
Cultivated land		97826	94034	86219	81467		*-16.7*	*-13.3*
Yard land[1]		6938	7068	9244	12129		*+74.8*	*+71.6*
Forest land		56398	59804	63936	68017		*+20.6*	*+13.7*
Grass land		131847	124597	126096	123858		*-6.1*	*0*
Dwelling area		3744	4045	4056	4078		*+8.9*	*0*
Traffic land		1017	1171	1175	1177		*+15.7*	*0*
Water		3420	3406	3403	3325		*-2.8*	*-2.4*
Unused land		917	916	912	912		*0*	*0*

[1] Includes fruit trees
Source: Land Use Office Ansai County (collected 2003)
*Ansai County Statistical Bureau (collected 2003)

From data collected in Danangou Watershed, the decrease of cultivated land is much larger (table 8), showing an 85% decrease of land used for agriculture. On the other hand the availability of flat land has increased and some of the land is still rainfed.

Table 8: Change of cultivated land area between 1982 and 2002 in Danagou Watershed.

	Total cultivated land area* *(m²/person)*		***Total cultivated land area*** *(m²/person)*		***Mean total cultivated land area*** *(m²/person)*, ***with variations in brackets***
	Hillslope	*Flat*	*Irrigated*	*Rainfed*	
1982	3960	290	180	4060	(4240-4250) ~ 4245
2002	580	410	200	950	(990-1150) ~ 1070
1982-2002	-3380	120	20	-3110	-3175
Land area change in percent (%)	-85%	41%	11%	-77%	-75%

* *The measurement of land is generally done in mu. One mu was originally defined as "the area a cow can cultivate in one day" and equals 666.7 m^2.*

Comparing the available hillslope/person from 2002 to 1982 shows a decrease by 85%, while the available flatland/person has increased by 41%.

On a regional scale, there has been a vegetation increase in the form of a higher chlorophyll activity over the period following the start of the Cropland Conversion Program. This is shown in MODIS vegetation indices (fig. 19).

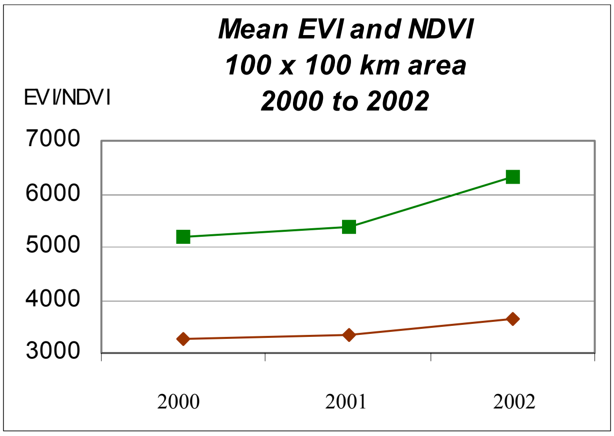


Figure 19: Vegetation indices from MODIS covering 2000-2002.

When looking at the geographical distribution of the increase, it is possible to see an even spread of the changes covering an area of 100 x 100 km with Ansai town in the middle (fig. 20).

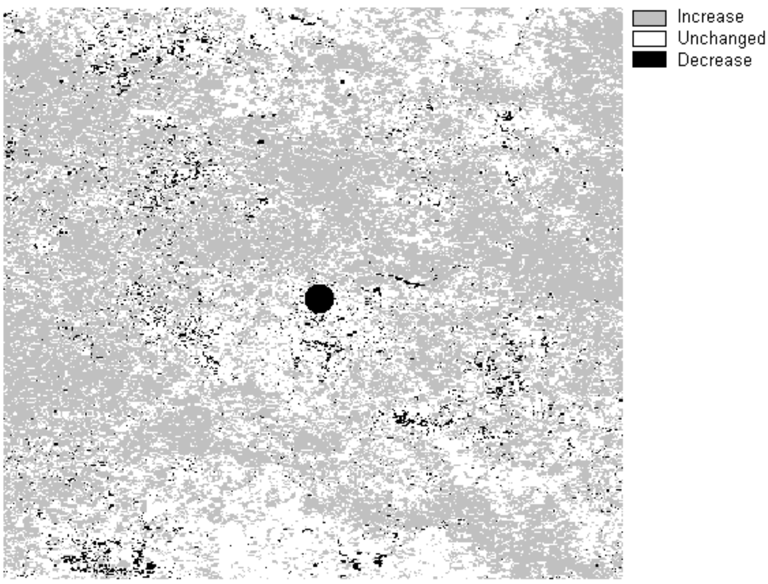


Figure 20: Increase, unchanged and decreased NDVI values from MODIS. Ansai town is represented with the big black dot in the middle.

Given the fact that the Cropland Conversion Program gave incentives to halt agricultural activities on slops in 1999 by planting seedlings, the degree of chlorophyll activity in the month of August from 2000 to 2002 could be the result of increasing number of trees and/or the fact that they are growing. The vegetation data from MODIS can also be affected by increased precipitation. From 1999 to 2002, the yearly precipitation from the weather station in Ansai was 346, 365, 546 and 542 mm, respectively.

*Table 9: Lagged correlation between MODIS vegetation indices (100 x 100 km) and temperature (mean) and precipitation (total). One month means that the climate data is one previous month ahead of the vegetation data. * indicates the significance level at 0.01 according to Pearson's test.*

		1 month		**3 months**		**6 months**		**1 year**	
		P	*T*	*P*	*T*	*P*	*T*	*P*	*T*
NDVI	*mean*	0.62	-0.98*	0.99*	-0.99*	0.97	0.93	0.95	0.71
	max	-0.11	-0.82	0.71	-0.59	0.53	0.92	0.42	0
EVI	*mean*	0.32	-0.98*	0.94	-0.88	0.83	0.99*	0.77	0.42
	max	0.94	-0.74	0.85	-0.92	0.95	0.59	0.97	0.97

By correlating the vegetation indices from August of each year to temperature and precipitation preceding that month in different laps (table 9) it is possible to see that no correlation was found with max vegetation values from MODIS, while mean values showed a few relationships. Negative correlation was found with temperature taken one to three months before August, which suggests that decreasing temperature is positive for increased vegetation e.g. less evapotranspiration. Correlation was also found with EVI and mean temperature half a year before August, which can indicate that warm springs have positive effects on chlorophyll activity for the rest of the growing season. Precipitation only showed correlation with NDVI in one instance, three months total precipitation before August, which coincides with correlated temperature. During the monsoon, the relationship between temperature and precipitation is crucial for vegetation, which the result shows. It also indicates that NDVI is more sensitive to climate variables than EVI. Hence, the regional increase in vegetation seen in the MODIS data is to certain degree correlated to climatic factors.

3.2.2. Climate sensitivity of primary production

As indicated above, the growth in vegetation seen in the MODIS data indicated a correlation with climate factors. Here, the climate scenarios were first run with the temperature scenario separately and then with the combined temperature and rainfall increase through changing the inputs in the different steps of the model above and repeating them.

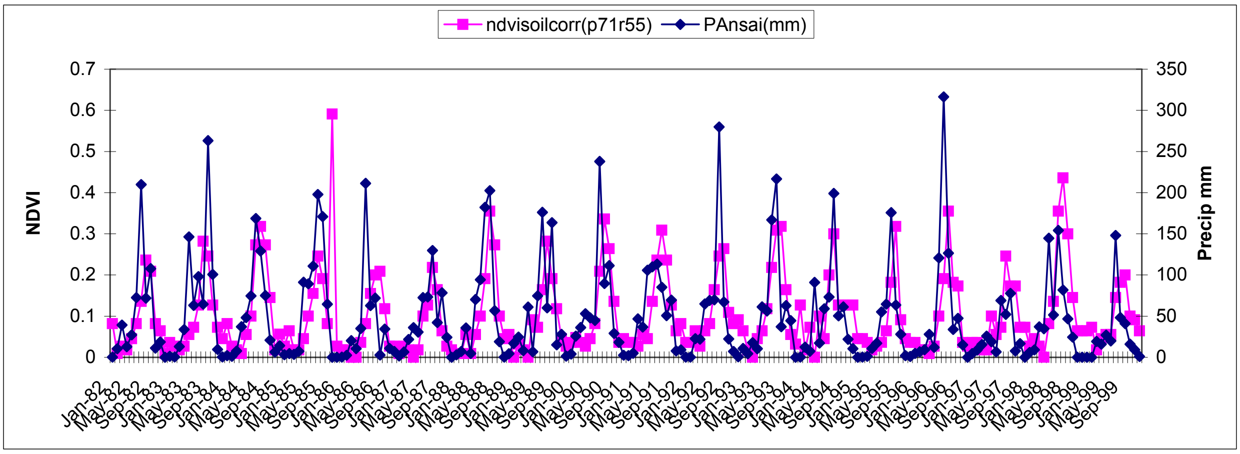


Figure 21: Monthly soil corrected NDVI and monthly precipitation over the growing season 82-99.

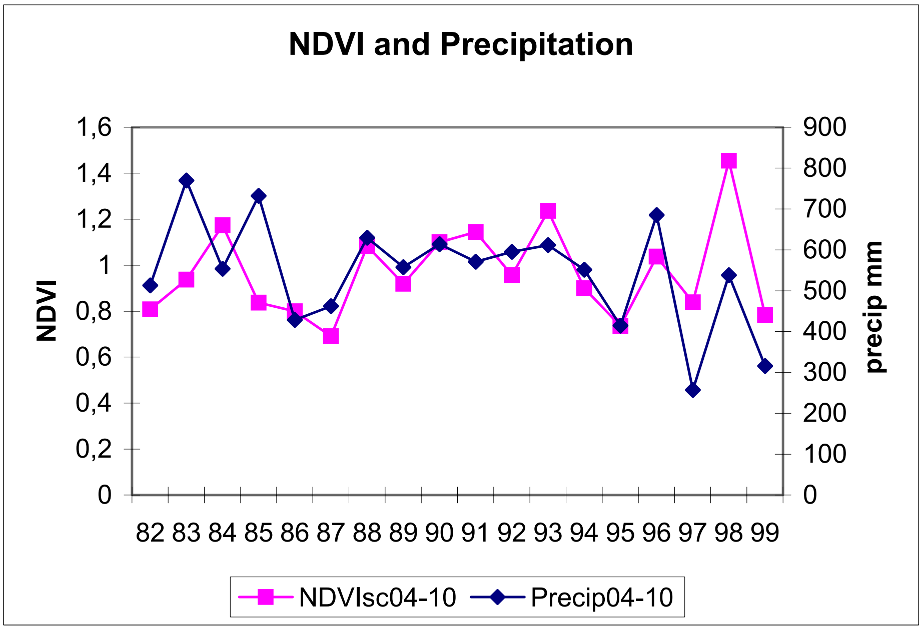


Figure 22: Annually accumulated soil corrected NDVI and annually accumulated precipitation over the growing season 82-99.

The two figures above (fig. 21 and 22) show the relation between NDVI and precipitation, both for the growing season, but also on an annual basis. While the precipitation shows a clear decreasing trend, NDVI stays more or less at the same level. This may be explained by the increasing measures taken to halt vegetation cover decline and forestation projects. As a consequence of the seasonal changes the Pearson r-squared values computed from correlations between monthly NDVI and precipitation becomes rather high (0.31 in fig. 23) in comparison with the annual growing season (April –October) summed correlations (0.15 in fig.24). The growing season summed correlations are also considerably lower in the Ansai region in comparison with two somewhat drier sites in the Inner Mongolia Autonomous region over the same time period, with the average precipitation amount of 398 mm and 344 mm annually, where Pearson r-squared reached 0.31 and 0.71 respectively (Brogaard et al. 2004)

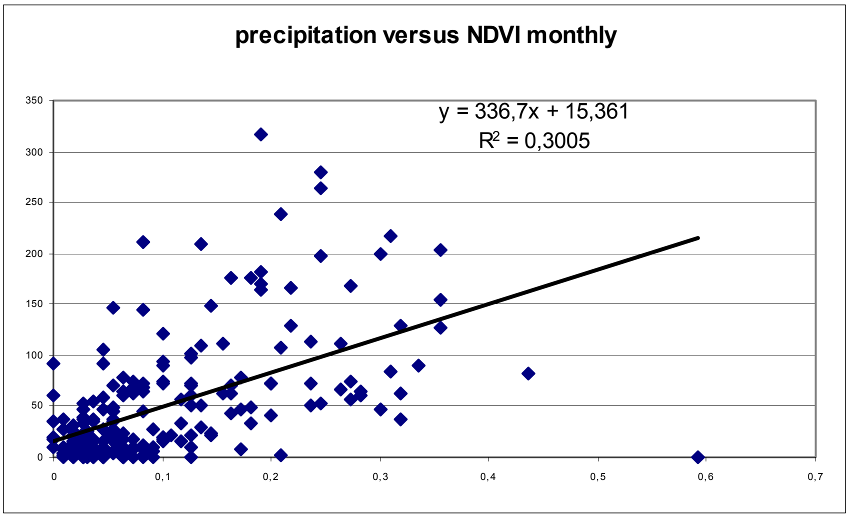


Figure 23: Correlations between growing monthly NDVI and Precipitation.

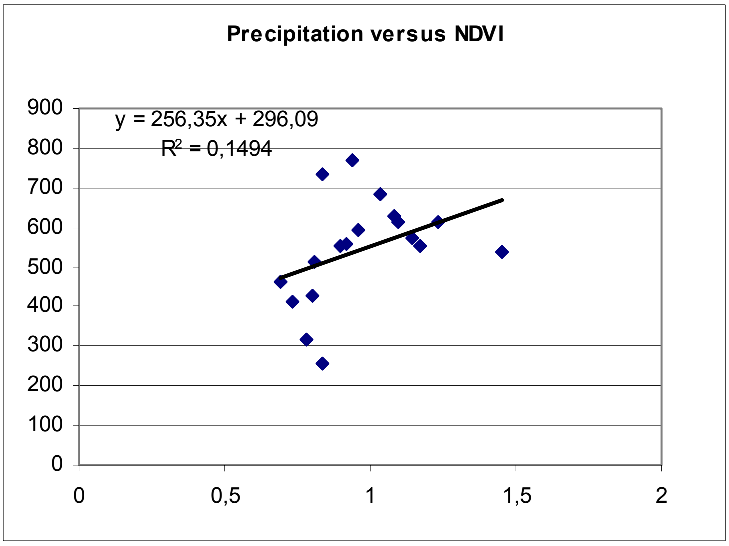


Figure 24: Correlations between growing seasons accumulated NDVI and Precipitation (April- October) 1982 to 1999.

The water stress calculations for the 18 year period is 0.75 which shows a considerably higher value (meaning lower water stress as the value should be looked on as 1-water stress) compared to the two figures for the Inner Mongolian sites which were around 0.5 (Brogaard et al. 2004). The coefficient of variation is about half for the Ansai region, 19%, in comparison with the Inner Mongolian sites ranging from 40 to 50%.

The computed GPP for the Ansai region (fig. 25) amounts to an average of 1300 g dry matter per m^2 annually, with a coefficient of variation of 30%. This is approximately equal to a value of above ground net primary production of 975 g [1300 x 0.75 (growth respiration) x 0.64 (maintenance respiration] x 0.42 (above ground fraction)].

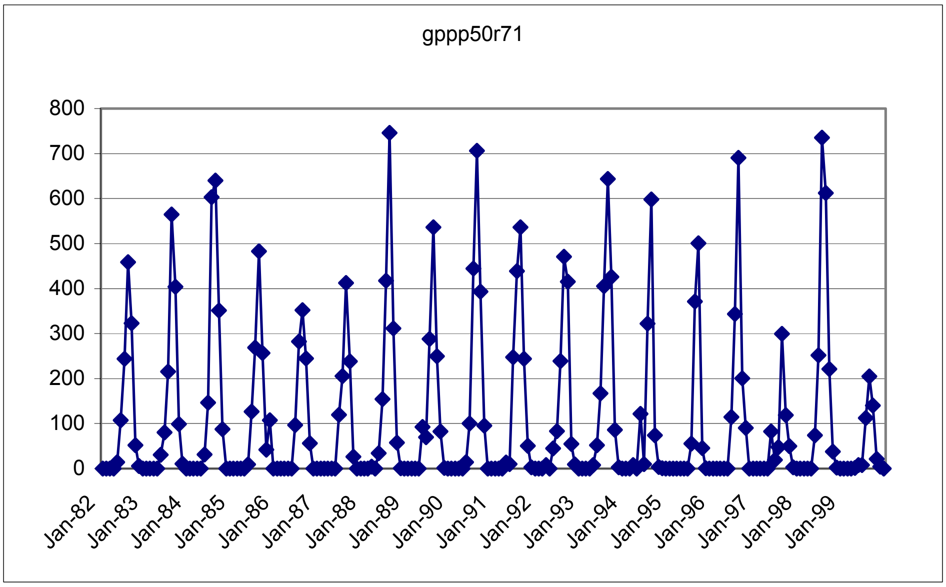


Figure 25: Gross primary production over the Ansai pixel at existing climate 1982-1999.

The increase in potential evapotranspiration between the original Ansai data set and the temperature scenario as computed in fig. 26, amounts to 230 mm per year.

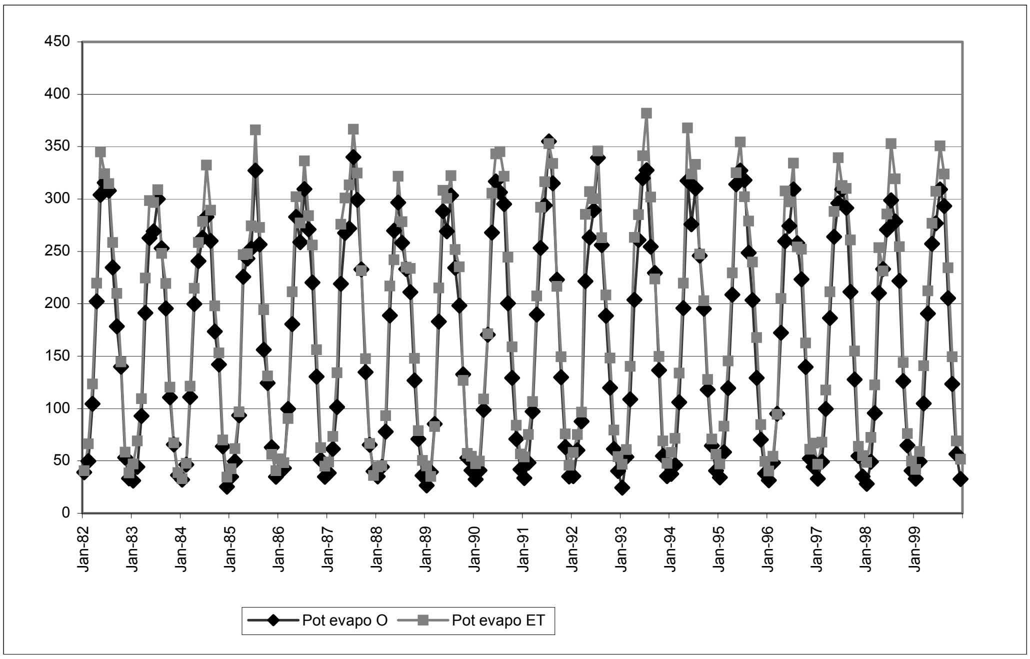


Figure 26: Potential evapotranspiration computed with the Hargreaves method for the original Ansai data (Pot evapo O) as well as the ECHAM4 Scenario A2 (Pot evapo ET).

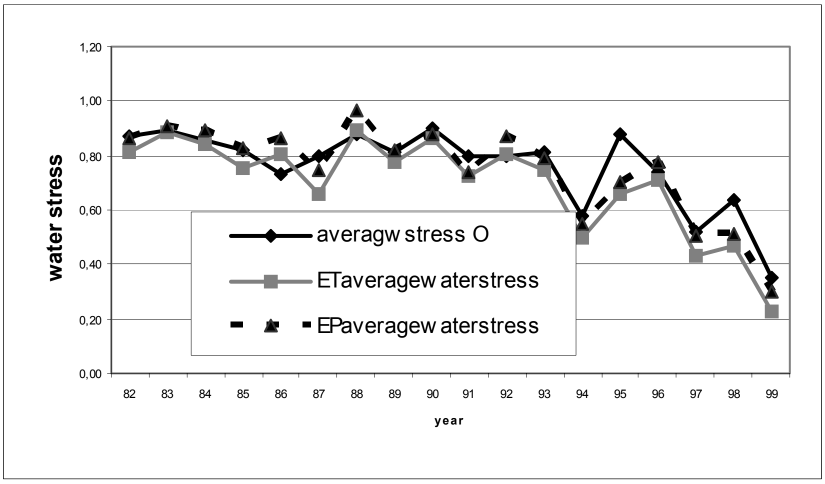


Figure 27: The seasonally average water stress (1-water stress –higher value means lower stress) for the original data (O) as well as the ECHAM temperature scenario (ET) and ECHAM combined temperature and precipitation scenario (EP).

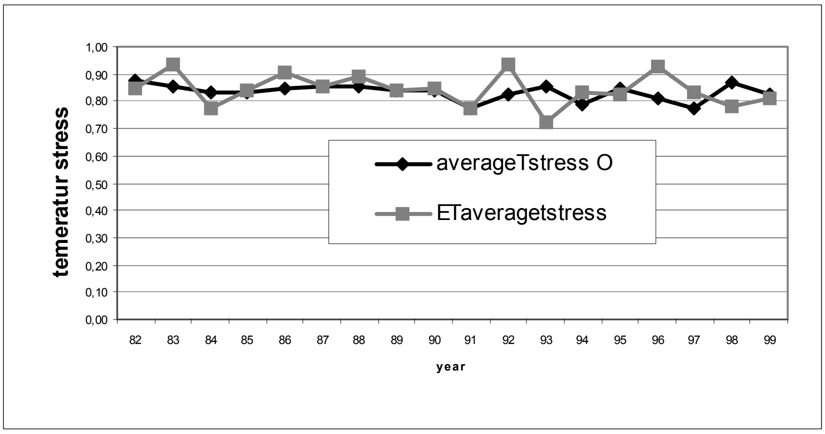


Figure 28: The seasonally average temperature stress (1-temperature stress –higher value means lower stress) for the original data as well as the ECHAM temperature scenario (ET).

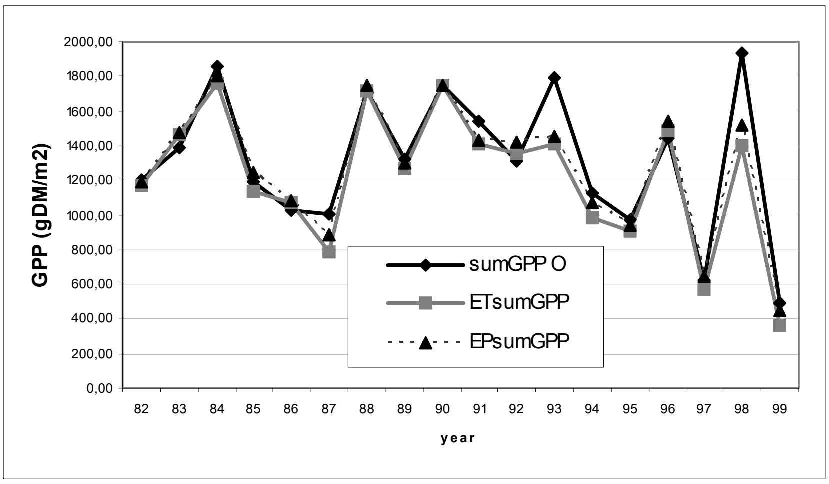


Figure 29: The seasonally average Gross Primary Production for the original data (O) as well as the ECHAM temperature scenario (ET) and ECHAM combined temperature and precipitation scenario (EP).

The computed GPP based on original observed data in the Ansai region shows a difference when compared to the ECHAM4 scenario A2 computations (2051- 2068) through changes in water and temperature stress applied on the 18 year time period 1982-1999. The original climate data gives the highest annual GPP (fig. 29). The decrease in the hydrological stress when adding about 90 mm precipitation annually does not fully compensate the increase in temperature as foreseen by the ECHAM temperature scenario for the same time period as computed in this model. This is particularly marked for the years 1987, 1993 and 1998. The temperature stress increases in dynamic for the scenario although the mean value is nearly maintained.

It should be kept in mind that in this preliminary analysis the NDVI value has been kept constant when changing the climatic parameters.

3.3. Interviews

3.3.1. Group interviews 2002

The expressions of direct adaptations to climate change were relatively few during the six group interviews conducted in May 2002. Instead, all six groups emphasised the importance of the development of markets for agricultural products and labour, and the recent conversion of slope farmland to forest and grassland.

During two of the group discussions, the planting of trees were mentioned as a way to mitigate negative impacts of climate variations or climate change. A woman in Leipingta expressed her ideas about the relationship between the policy of planting trees on hillslopes and climate variations:

> *"It will rain more when the trees are grown up. The leaves can absorb the moisture in the air. If you follow science it will rain more. This is my opinion. That is the profit from planting trees. The trees can fight the drought, flood and the heat."*

A male group in Leipingta also expressed the view that planting trees have an impact on rainfall:

> *"Because of more trees all the water goes into the soil. When it is sunny there will be more evaporation and therefore more rain."*

Two of the men in Leipingta stated that they plant earlier today than before because of the warm weather, but this adaptation was not mentioned by any of the other groups.

Having revealed that many of the farmers had changed their choice of crops in recent years through individual interviews, we wanted to find out whether the four groups linked this change to climate change or if there were other factors influencing the change of crops. We therefore asked four of the groups why they had changed their crops in recent years.

One of the female groups in Danangou discussed the choice by many of the farmers to grow vegetables and potatoes rather than grain. One woman argued that they plant vegetables to sell on the market so that they can buy wheat. Another woman said that they plant crops with higher yield. The group further agreed that:

"In the past we planted crops on the hillslope and could not get a good harvest. Now we plant trees on the hillslope. We only plant crops on small good areas on the hillslope".

Talking about potatoes, the women explained that they had always grown potatoes, in fact even more before than today. They plant potatoes since the yield is high, the taste is good, it is their main dish and can be easily sold on the market.

The female group in Leipingta stated that they continuously change their crops in a rotation system. One year they plant foxtail millet, the second year they plant pearl millet, and the third year is for potatoes, corn or soybeans. However, continuing the discussion about the choice of crops, the women agreed to a recent change of crops:

"Now we plant more of the corn, potatoes, soybeans and sunflower. It is easier to get rid of the weed with these crops, and we can sell for money".

One of the male groups in Danangou stated that the reason why farmers have changed their crops is because the policy has changed. Since 2001 the farmers in Danangou and Leipingta do not plant crops on the hillslopes. This group also mentioned the fact that many of the farmers go out to do off-farm work as a reason for changes in choice of crops.

The male group in Leipingta argued that the farmers prefer wheat instead of millet. They plant potatoes and corn instead of millet and they buy wheat. One of the farmers said that millet is very cheap while potatoes and corn can be sold for more money. One of the farmers changed from soybeans to sunflowers last year. The reason for the change was that both the price and the yield from sunflower seeds were better than from soybeans. The group summarized their discussion in the following words:

"The reason for changing crops lately is because we can get a higher price and a higher yield. We cannot earn money from other things".

Further, a male group in Danangou discussed building materials for houses. They all agreed that the materials used for building a house depends on the economic situation for household in question:

"The rich use bricks, the medium use stones and the poor use soil or cave houses".

When we asked the group what kind of house they preferred, they claimed that:

"Soil/cave house is warm in winter and cold in summer. The rich people want brick houses because they are beautiful. Rich people can put in a stove if it is cold in the winter".

All six groups emphasised the importance of markets for agricultural products as well as labour, and the recent Cropland Conversion Programme. This was especially clear when we asked the six groups about their thoughts about the future. One of the female groups in Danangou emphasised the impact of the Cropland Conversion Programme:

> *"Now we plant trees on the hillslope, so there is no development for the agriculture in the future. We can't only depend on planting".*

When we asked the female group in Leipingta if they thought that the village can develop, one woman replied:

> *"Can you develop a village on only planting trees? Only the old people stay in Leipingta. The young people do off-farm job".*

One of the male groups in Danangou agreed that there is no future in farming, since it is hard and badly paid. You earn more money if you do business. The reason why so many of the farmers have started to do off-farm work is, according to the group, that they have less land now than before and therefore they have more free days to go out and work.

The female group in Leipingta wanted their children to be rich, to become high officials or to go to the University. One of the female groups in Danangou expressed the wish that their children would go to University and even study abroad. They didn't want their children to live in Danangou. When we asked this group about the future of Danangou, one of the women replied:

> *"I don't know. If we can find oil in this region and build a road there is a future. The village could develop".*

We asked one of the male groups in Danangou what they would prefer to do, off-farm work or agriculture, and they all stated that they wanted to do agriculture. One man explained:

> *"I want to plant the land. Off-farm job sometimes will not support us. Off-farm job is not long-term. First we want to plant land and in our spare time we can do off-farm job."*

Another man continued:

> *"We want the government to help us in the village. If I get a job in town it will only help me, not the next generation. If the government help us to build terraces and dams it will also help our grandchildren. You can also fish in the dam. If we get help with building dam and terraces we can use the water to irrigate and raise fish in the dam."*

When we asked the male group in Leipingta if anyone would do farming in the future they replied:

> *"It is certain that someone will stay here and do farm work if they cannot find other jobs or go to the University. We wish our children will get other jobs. The farm job is very hard, it is the hardest job".*

Both women and men claimed that even though they have decreasing possibilities to depend on agriculture for their livelihoods, the living standard is better today than before.

A woman in Danangou stated that it is more economic to buy food than to plant it. When a female group in Danangou was asked whether they wanted the hillslope land back for planting of grain, they agreed that they didn't want this land back. It was better now. The same argument was given by a male group in Danangou when we asked them if the living standard today is better than before:

> *"The living standard is higher now than before. Compared to other regions it is low".*

3.3.2. Structured and semi-structured individual interviews 2002

The present day land-use pattern in Danangou and Leipingta has been influenced by complex interaction of a number of factors since 1982. A comparison of the main crop planted in 1980s and 2002 shows a transition from mainly planting millet to a diversification of crops planted (fig. 30).

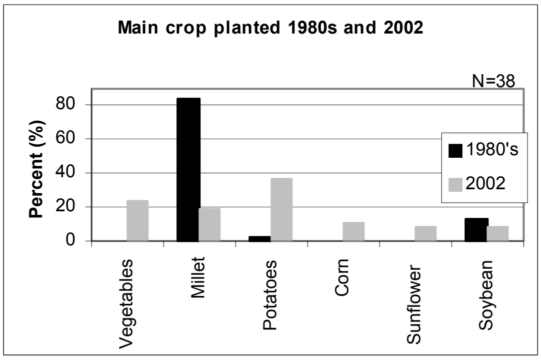


Figure 30: Main crop planted in the 1980s and today. (Adopted from Hageback et al. 2004)

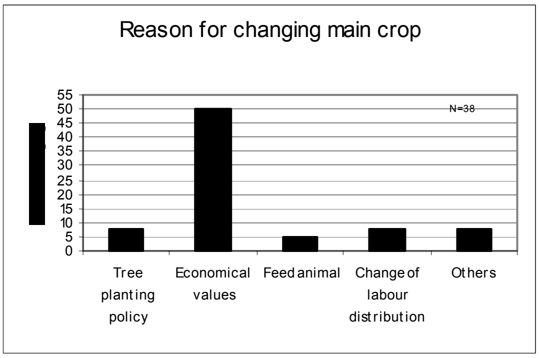


Figure 31: Reason for changing main crop. (Adopted from Hageback e tal. 2004)

The major reason for this transition is economic (fig. 31), e.g. compared to the 1980s; the farmers today have a possibility to grow cash crops and subsequently increase their income. However, there are additional factors influencing this transition. Even though less than 10% of the households in Danangou and Leipingta state the Cropland Conversion Programme as the major reason for changing main crops, 58% state that they changed their main crop between 1997 and 2002. Further, two kinds of plastic cover have been introduced since 1982, as described in fig. 18: during 1982 – 1983, land plastic cover was introduced in Danangou and Leipingta by the government and is today widely used for growing vegetables, potatoes and corn. During the 1990s, shelter plastic cover was introduced and is today also used widely by the farmers to raise vegetable seedlings (Hageback and Sundberg 2002).

Chen et al. (2001) studied land-use change due to the introduction of the Household Responsibility System by interpretation of two aerial photographs (1975 and 1997). The results show a decrease of the total area percentage of terrace farmland from 3.4% to 1.7%, and a decrease of slope farmland from 40.1% to 35.4%. The reason for the decrease of slope farmland is believed to be the decreased availability of labour due to the transition from a collective village work force before 1982 to labour limited to the household after 1982 (Chen et al. 2001). In 2002 (after the introduction of the Cropland Conversion Programme) the decrease of slope farmland is even more obvious (table 8, under results from Land use). Even though only 10% of the households in Danangou and Leipingta state the Cropland Conversion Programme as the major reason for changing main crop, 58% state that they changed their main crop between 1997 and 2002 (Chen et al. 2001). The access to water for irrigation has increased in Leipingta but decreased in Danangou. In 1958 a channel used for irrigation in Danangou was built. However, a part of the channel was destroyed by a gas-pipe explosion and was never rebuilt. As a result, a few households in Danangou do not have access to water for irrigation today. In Leipingta, the access to water for irrigation has increased by 44% since the 1980s.

In 2002, 79% of the households in Danangou and Leipingta received non-farm income, 18% of which started non-farm work in 1982 while 41% started after 1997 (Chen et al. 2001).

3.3.3. Structured interviews 2003

The fact that almost 80% of the households in Danangou and Leipingta receive non-farm income, does not reveal the impact of non-farm income on total income. Results from structured interviews of 22 households in April/May 2003 show that the share of non-farm income in relation to total income for the two villages was 73.4% in 2003. The share of non-farm income was 65.1% in Leipingta, and 90.4% in Danangou. The reason for the difference between the two villages is probably that Danangou is situated closer to the main road and thereby having easier access to local economic centres, for example Ansai town. Further, while the share of non-farm income in relation to total income among poor households (less than 6 000 yuan in gross income in 2002) in 2002 was 51%, the figure for middle income households (from 9 000 to 20 000 yuan/year) was 82%. This difference indicates that poor household have less access to non-farm income generating activities. In fact poor households are characterized by their exclusion from non-farm activities that demands initial economic investment. A very important result is that women’s contribution to non-farm income was only marginal; meaning that with an increasing share of non-farm income in relation to total income, the share of women’s contribution to the household economy is decreasing, since women are predominantly involved in farm activities.

These simple economic indicators can be related to results from a survey on land use in 2003, covering the same 22 households (table 10).

Table 10: Land use in Mu/household based on survey 2003 covering 22 households. The column CCP indicates slope cropland converted to forestland. The column Trees outside CCP indicates land where trees are planted outside the CCP. Poor households had a total gross income below 6 000 yuan in 2002. Middle-income households had total gross income between 9 000 and 20 000 yuan in 2002. Rich households had a total gross income exceeding 23 000 in 2002.

	CCP	Potato	Corn	Millet	Bean	Sunflower	Trees outside CCP	Vegetables	Unplanted	TOTAL
Whole sample	8,9	2,1	0,6	1,1	0,3	0,3	0,8	0,6	5,9	20,6
Danangou	5,2	1,5	0	1,25	0	0	0,15	0,7	10,25	19,05
Leipingta	14	2,9	1,4	0,8	0,8	0,8	1,8	0,3	0	22,8
Poor households	9	1,6	1	1,7	0	0,5	0,2	0,3	0	14,3
Middle income households	9	2,3	0,5	0,5	0,3	0,2	1,5	0,7	7,7	22,7
Rich households	8,56	2,25	0,8	1,2	1	0,4	0	0,5	7,6	22,4

What is worth noting from this table is firstly the significant share of land converted to forestland. For the whole sample, this category of land constitutes 43% of the total household land. In Leipingta the percentage is even higher, 61%. But what is the impact of the land conversion on the households' livelihoods (fig.32)?

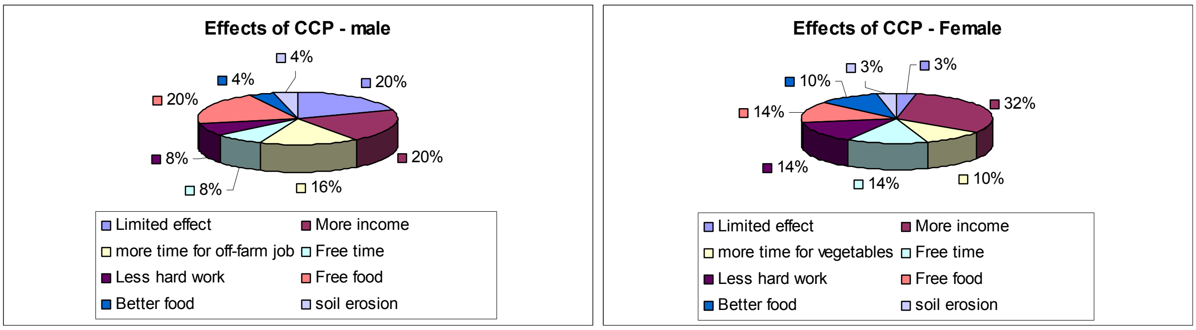


Figure 32: Effects of the Cropland Conversion Programme. Results from structured interviews 2003 covering 22 households.

The results from structured interviews 2003 indicate that both men and women perceive increased income as the most important or very important effect coming from the implementation of the CCP. While 16% of the men acknowledge that they now have even more time for off-farm activities, 10% of the women said that they now have more time for growing vegetables than before. While 20% of the men point at the food subsidies of the CCP as an effect, only 4% of the men see a change towards better food. 14% of the women acknowledge the food subsidies as an important effect of the CCP, and 10% see a change towards better food. While 14% of the women mentioned more free time as an effect, only 8% of the men mentioned this as an effect. It is perhaps surprising that only 4% of the men and 3% of the women mentioned decreasing soil erosion as an effect of the CCP. An important general conclusion is that women see more positive effects of the CCP (only 4% stated that the CCP had a limited effect) than the men (20% stated that the CCP had a limited effect).

Secondly, there is a very clear difference in land use between Danangou and Leipingta. The amount of land converted to forestland per household in Leipingta is more than double than that in Danangou. The amount of land used for growing vegetables in greenhouses in Danangou is more than double than that in Leipingta. Further, while more than 50% of the household land in Danangou was unplanted in 2002, all household land in Leipingta was used in one way or the other. These differences are explained firstly by differences in the quantity and quality of the land to which the households of each village have access. Secondly, the high share of uncultivated household land in Danangou can be linked to the higher share of non-farm income in relation to total income. The households in Danangou simply don't have enough labour force to cultivate all available land, since a majority of the work force is allocated to non-farm activities. This explanation is further strengthened by the fact that the Danangou share of income from non-farm business and labour in the total sample was 63%.

Thirdly, poor households have less land than middle income and rich households. Poor households are above the total sample average when it comes to subsistence crops such as corn, millet and sunflower, but beneath the average when it comes to crops that generate cash, such as potatoes and vegetables. However, the most striking difference is that while poor households have less land than the other income groups, the other income groups did not cultivate a substantial part of their land. Rich and middle income households do not use more land than poor households, rather they leave land uncultivated since they earn more from allocating labour to non-farm activities. This is a problem that has been noted in other parts of China (Benjamin and Brandt 1999). The egalitarian distribution of farmland of the Household Responsibility System may prevent households from exploiting their comparative advantage, e.g. there are few transfers of land from richer households that are more engaged in non-farm activities, to poor households with few non-farm opportunities. In this sense, the egalitarian distribution of land might in fact increase the inequality effects of diversification (Benjamin and Brandt 1999).

We can therefore conclude that policy and socio-economic changes that has taken place in the study area since the end of the 1970s, in the forms of land tenure reform, economic liberalisation and the Cropland Conversion Programme, have had a tremendous effect on land use. In fact, all these changes have tended to work in the same direction; towards an increasing share of non-farm income in relation to total income. This trend has reached a point where middle income and rich households even leave land unplanted in favour of more profitable income generating activities. Furthermore, our results indicate that there are important differences between villages, between households and even within households. For example, the poor households are often excluded from the most profitable non-farm activities due to lack of capital for investment. They still have to rely on their agricultural land to a higher degree, despite the fact that they have less land than rich and middle income households, and despite the fact that they have fewer opportunities to grow cash-crops. In general this means that the poor are more vulnerable to negative effects of climate change, simply by being more dependent on rain fed agricultural production.

3.4. Integration of results

3.4.1. Meteorological records versus perceptions

Climate is showing variability in the Ansai area, the temperature increase more significantly than precipitation that shows an augmented fluctuation both in timing and amount of rainfall.

With the climate analyses presented above, we have also linked the larger scale climate pattern at present and in the future to our study area, i.e. taken the debate of impacts of climate change from a general discussion down to local-scale.

The change in temperature and precipitation are of farming relevance. During “climate game” exercise with farmers there were seldom any discussion about the past change in temperature, since they all agreed about the steadily increase since 1962, which correlate well with the climate date. They exemplify this by describing change of clothing, where they before had to dress in thinker clothing or that water use to freeze in the early days. The farmers distinguish the fact that it is particularly the winters that have changed, which also is found in the meteorological data.

Several opinions and point where exposed during the “climate game” exercises such as:

- It is easier to remember a flood or a drought (i.e. extreme event) than remember the general rainfall over one decade.
- The rain has always varied so it is hard to remember all the fluctuations.
- There is a balance in the rain over a 10-year period with 5 dry and 5 wet years, which makes in hard to do the “climate game” with 10 years.
- The rain is temperature dependant and since the temperature has increased they have received less rain.

In discussions, weather fluctuations were also mentioned.

> “The former weather was very certain… now it is very uncertain”

So the changing weather is perceived. From farmers’ point of view, this is not necessarily bad. More warm weather will cause the crops to grow faster, which would benefit farmers. Many villagers also appreciate the warmer winters for their own comfort. With regards to the rainfall, farmers need water for farming but acknowledge the decreased dependency on rainfed agriculture, due to more flatland agriculture and increased irrigation possibilities.

3.4.2. Farmers’ adaptation to changes

As has been explained above, there are several changes taking place in the area of Ansai, one being the climate that was the starting point of this project. However, two very marked changes that have been found during the study; the change of the socio-economical setting with i.e. a marked increase in off-farm income and the change of land use induced by the Cropland Conversion Program.

Adaptation can be described as a response that improves the outcome and that implied that there is a change taking place or is anticipated to take place (Reilly and Schimmelpfennig 2000; IPCC 2001). These adaptations can take place autonomously (without conscious planning) or non-autonomously (planned) and their effect can have either restricting of opportune effects, which many times depends on whether the change is happening suddenly through shock (often large direct impact) or through cumulatively change (often small and regular).

With regards to climate, the farmers have consciously seen the climate change and hence adapted where they find the need, e.g. plant earlier or wear lighter clothing. But due to the simultaneous changes, they have altered their way of earning income (off-farm work and subsidies from the CCP) and of using their land (no hillslope agriculture, less rainfed agriculture, more flatland focus).

With regards to the socio-economical situation it is clear that the villagers have adapted to a more market oriented economy which they regard as “better now than before”. They appreciate not being dependent of only farming and the prospect of a non-farm life. They grow products that are sold on the available market which generates money that gives them buying power. The outcome of farmers’ adaptation is not always viewed positive in terms of off-farm job. The villagers see the off-farm jobs as unreliable and many times they have to leave their homes for longer period of times to work. Also, the self-sufficient life-style that came from subsistent farming is now experienced and many farmers express the dependence of sources from outside the village.

With regards to land-use change, the Cropland Conversion Program was planned at the national level as a measure to halt erosion and hence sedimentation problems in the big rivers. Its purpose was not to accommodate farmers with solutions to combat unreliable climate even though the program is welcomed in many senses. One is that with absence of hillslope farming, the focus can be put on the more productive flatland, which has increased its production mainly on cash generating crops. It has freed labour causing an increase in the off-farm sources. Thus, even though the intent was not to adapt to climate variability by changing the land use, there has certainly been a change to which the farmers have adapted in favour of the present climate trend in the area.

With the present changes and adaptation, the question is if the inhabitants of this area are over-adapting to the point that there is no turning back, in the sense that one of several ongoing changes might stop, reverse of simply change. Such a possibility is that the present weather condition may be due to a 20-30 year oscillation cycle (Hageback and Sundberg 2002) and could return to a wetter and colder climate in a few years. Scenarios made in this study indicate a wetter future than has been experienced the last decades. Or there might be a change in available off-farm jobs or change in markets for agricultural produce. New policies might be introduced. In that respect the issue of resilience is of relevance.

3.4.3. Factors driving present farming and land use

Very handy, in times of climate variation, is the impact of Cropland Conversion Program and the increased market oriented economy. All of these changes have affected the way that land is used and farmed. Seen from an ecological and environmental point of view, the present change is for the better, locally (less erosion) and nationally (less sedimentation). Seen from the economical point of view, farmers get subsidies and through freed time greater possibility to make money in other ways. With the present focus on the Cropland Conversion Program, the big hurdle so get over and adapt to, is the change that will happen in 2008 when the farmers will no longer get subsidies from the conversion. The transition can have environmental, economical and social impacts.

The great majority of villagers airing their opinion through discussions wish their children out of farming, which also can be seen in the expenditure on school related activities. Education is the fourth most important expenditure in Danagou Watershed (9.9% of total expenditure) and make up as much as 15% of total expenditure in middle income households (Knutsson 2004).

Farming is mainly seen as the worst alternative for job in this area, an opinion that might be explained historically by cultural tradition and value, income, and the social security system with the household registration system (hukou) and the work unit system (danwei). All these factors have limited farmers prospective to a great extent as well as put them in the lower part of the social system. The question is whether farming in this area, with soils of high erodibility and steep hills plus inhabitants that wish getting out of farming, is desired in the future? The debate on the needed food production in China is lively (e.g. Yang and Huang 1997; Hubacek, 1999; Heilig et al. 2000).

4. FUTURE PERSPECTIVES

In this study the land use and climate change at a local scale have been the focus. The detailed data made it possible to track the local change and to investigate the cause-effect relation. It has been demonstrated that this kind of study is useful to understand local impact of climate variability and/or policies. A project proposal focusing on the continuation of collecting data on changes in climate, land use and socio-economy has been developed during early 2004 with hopeful continuation in 2005. This type of local study would benefit regional or national multi-sector analyses, as has been proposed by Reilly and Schimmelpfennig (2000), Magistro and Roncoli (2001) and Vedwan and Rhoades (2001).

However, in order to make the study even more useful for decision making, the local system has to be put into the dynamics of a larger system, i.e. the regional level. Also, how the regional level would be impacted by the local level dynamics is of relevance. Thus, the interaction between the regional and local levels should be considered as one of the future directions.

4.1. Impact of climate change on regional level agriculture

As a consequence of the project presented here, a PhD project was initiated in October 2002 at Physical Geography, Göteborg University. In January 2003 the project received funding from Sida (SWE-2002-038). The project is focusing on the link between climate and agriculture productivity. The overall aim is to perform climate impact studies on agriculture and forest production in Shaanxi and Beijing Province by evaluating the role of regional climate (temperature, precipitation and soil moisture) on productivity. Further the project will develop links between local climate and topography as well assess future impact of climate change on the production by using IPCC's climate change scenarios. This will hopefully provide policy makers with useful information for adaptation strategies in the area. The project will run until 2007.

4.2. Climate change in a livelihood perspective

Development, sustainability and equity are central and integrated concepts of the *Sustainable Livelihoods Approach* (SLA*)*. The Sustainable Livelihoods Approach is envisioned as a holistic understanding and analysis of the complexity and diversity of rural development, poverty and environmental management (Chambers and Conway 1992; Ellis 2000; Scoones 1998; ODI 2002; UNDP 1999). Fundamental to the approach is the elaborations of policy-oriented livelihood frameworks, opening up a possibility of describing and analysing driving forces, pressures and impacts of all types of activities related to the local livelihood situation (fig. 33). There is a great potential of conceptually relating the SLA to recent literature and research on human adaptation to climate change. Adaptation literature, as well as the SLA, is concerned with the different capacities of human systems to respond to exogenous change. Classification of different capacities and definitions of degrees of change (regular, irregular, long-term, short-term, predictable, unpredictable, etc.) are in fact very similar, and they share several fundamental concepts such as vulnerability, resilience, coping ability etc. (c.f. Ellis 2000; IPCC 2001; Reilly and Schimmelpfennig 2000; Roncoli et al. 2001; Scoones 1998; Smit et al. 2000; Yohe 1999). A further relevant link is the focus on policy-relevant analysis and assessment. However, while most of the literature on adaptation to climate change is solely concerned with climate change as the factor to which adaptation is related, the SLA focus on the different ways and the extent to which human individuals or human systems are coping with and adapting to non-climatic transforming processes, as well as climatic shocks, trends and seasonality, with the overall function of assessing integrated livelihood outcomes in terms of income, well-being, vulnerability, food-security, and sustainable use of natural resources (Scoones 1998). Despite the potential benefits of linking the SLA to climate change-related research, there have been no systematic attempts based on empirical research as yet.

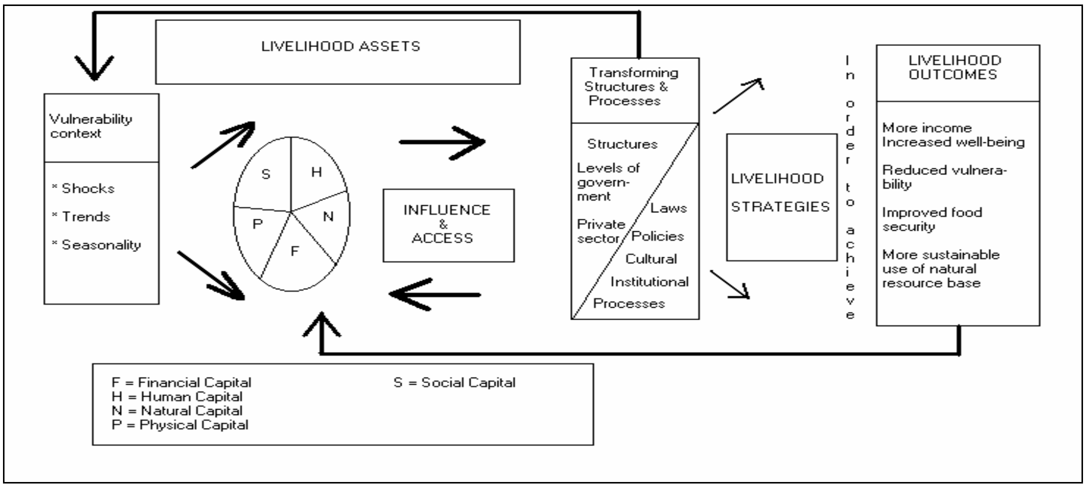


Figure 33: DFIDs framework for livelihood analysis. Adopted from Scoones 1998

The overall aim of the continued research (2003 – 2005) in Shaanxi Province is to analyse local adaptation to climate change in the Danangou watershed as an integrated component of the Sustainable Livelihoods Approach framework. Using the terminology of the SLA-framework developed by Scoones (1998), the proposed project will focus on obtaining indicators for livelihood components: (a) the vulnerability context in terms of impacts of and adaptation to extreme climatic events; (b) natural capital in terms of land and water use; (c) social capital in terms of the role of the household, extended family and village as social networks; (d) financial capital in terms of household income, sources of income, and expenditures; (e) human capital in terms of level of education and household labour power, (f) physical capital in terms of houses and a channel used for irrigation built in 1958; and (g) livelihood strategies in terms of agricultural production, migration, and off-farm labour. These indicators will be used in order to assess livelihood outcomes according to income, well-being, vulnerability, food-security, and sustainable use of natural resources. The project is conducted at Human Ecology, GU.

5. CONCLUSIONS

- Local temperature has increased with 1° during the last 32 years. The increase is strongest in the winter.
- During the last 32 years local precipitation has decreased with 14% (2.6 mm/yr), while regional precipitation has decreased with 19% (1.8 mm/yr) during the last 49 years. The interannual variability is large and there is a considerable decadal and interdecadal variability. During the last 20 years there has been a significant decreasing trend (95% significant level) in local precipitation (-11.7 mm/yr). The years from 1998-2001 were very dry.
- The local climate is showing similar trends as experienced on the regional level.
- The two global climate models show a similar increasing trend for the regional temperature for the next 100 years to come, while some difference exists between the precipitation changes in terms of timing and long term trend.
- The "climate game" has been an information-generating tool for this type of participatory work.
- Farmers' perception of climatic variability corresponds with the climatic data records. The farmers can give detailed descriptions of the climate for the last few years. Further back in time they recognize trends. They think it has become warmer, especially during winter.
- Reforms and policies have a stronger influence, in terms of the farmers' choice of cropping system, than climate variability on the land use in the study area.
- Regional vegetation patterns show correlation with climate parameters.
- The Cropland Conversion Program has drastically changed that land use in the area to up to 85% loss of previous agricultural area.
- During the last 20 years the farmers have switched from a dependence on agriculture to a more diversified livelihood due to economic changes and governmental reforms. This combination of planned and non-conscious planned adaptation makes the farmers less vulnerable to climate variability and can be seen as a responds to a changing situation, both climatologically and economically.
- Based on the interviews performed, the farmers wish their children not to be farmers.

6. DELIVERABLES

6.1. Publication in reviewed scientific journals

- Hageback J, Sundberg J, Ostwald M, Chen D, Yun X and Knutsson P (2004) Climate variations and land-use change in Danangou watershed, China – Examples of small-scale farmers' adaptation. Forthcoming in *Climatic Change.*
- Knutsson P, Ostwald M and Yun X (2003) The Significance of Climate Change in Rural Livelihoods – an Example From two Villages on the Northern Loess Plateau, China. Proceedings of the International Symposium on Climate Change (ISCC Beijing, China, 31 March – 3 April 2003). WMO/TD-NO.1172

6.2. Other publications

- Hageback J and Sundberg J (2002) Climate variations in relation to local scale land use and farmers' perception of climate in Danangou watershed on the Loess Plateau, China. Earth Sciences Centre, Göteborg University B335, pp 62

6.3. Attended conferences/conference presentations

- Deliang Chen, Madelene Ostwald, and Per Knutsson and Youmin Chen visited START Temperate East Asia Regional Center in Beijing in 2001. Prof. Congbin Fu (the director of the START Center) and Deliang Chen orgnised a minworkshop for the two teams.
- Deliang Chen, Madelene Ostwald, Per Knutsson and Youmin Chen attended International Symposium on Climate Change organized by National Climate Centre in Beijing in March 2003 with one poster and one oral presentation associated to the project.
- Madelene Ostwald presented a poster associated to the project at the Fall Meeting of the American Geophysical Union 2003 in San Francisco.

6.4. Other publications in preparation

- Ostwald M (2004) Land-use change: impacts of climate variations and policies among small-scale farmers. Manuscript
- Knutsson P (2004) The inequality of rural livelihoods in two neighbouring villages in Shaanxi Province, China. Forthcoming at the IRSA (International Rural Sociology Association) XI Congress, Trondheim, Norway, July 2004
- Ostwald M and Simelton E (2004) Correlation between land-use change and climate variables. Forthcoming at the 7th European Conference on Agriculture and Rural Development in China, London, UK, Sep 2004
- Knutsson P and Ostwald M (2004) Quantitative description of how to make a living – use of SLA among small-scale farmers. Forthcoming at the 7th European Conference on Agriculture and Rural Development in China, London, UK, Sep 2004
- A Chinese paper based on this report will be prepared in 2004.

6.5. Awards

- Per Knutsson was awarded for best presentation of a young researcher at the International Symposium on Climate Change organized by National Climate Centre in Beijing in March 2003.

6.6. Related studies and activities

- One Master Thesis from two students granted MFS (Hageback and Sundberg, 2002)
- Project seminar with all participants on 12 September 2002 (App 1 and 2)
- A Ph.D. project of Elisabeth Simelton (Physical Geography, Earth Sciences Centre, Göteborg University) started in 2003. the project is supported by Sida and focuses on soil moisture and regional impact in Shaanxi Province and Beijing area with risk-thresholds as an important method.
- Hans Linderholm (Physical Geography, Earth Sciences Centre, Göteborg University) has started up a project (Planning grant from Sida fall 2003) titled "Evaluating climate and ecological changes in the historical past using tree-ring data, Shaanxi Province, China" that will build on data and experiences from this project.
- A post doc stipend from FORMAS has been granted to Sara Brogaard for 2004-2005 to continue the work of climate sensitivity of primary production in the northern part of China- The project is focusing on the Inner Mongolli Autonomous region, but more results may also be produced for the Ansai region.

Acknowledgement

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Appendix

App 1.

Programme for Seminar

Impact of climate change and variability on local-scale land use in Shaanxi Province, China

12 September 2002
Ågrensaka Villan, Högåsplatsen 2, Göteborg

9.00-9.15	Coffee and tea
9.15-12.15	Presentations
9.30-9.45	Résumé of China trip in May – Deliang et al
9.45-10.45	Results from MFS study Danangou – Johanna & Jenny
10.45-11.15	Team Climate – Youmin 'Precipitation expanded downscaling and its result application to HBV hydrological model in a single catchment'.
11.15-11.45	Team Land Use
11.45-12.15	Team Social Cultural
12.15- 13.00	Lunch
13.00-13.20	New PhD project at Physical Geography GU – Elisabeth Simelton
13.20-14.45	Future 1. Help to the teams – lack of data, new ideas etc. 2. Joint field visit March/April 2003 3. Plan to participate at conference Beijing 2003 4. Articles and reports 5. Economic report - Deliang
14.45-15.00	Coffee and tea
15.00- 15.30	Possible method to integrate our data into one analysis – Per
15.30-16.30	Open for discussion

Participants

<u>Project group:</u>
Deliang Chen
Madelene Ostwald
Per Knutsson
Yun Xie
Sara Brogaard
Katarina Borne
Youmin Chen

<u>Other:</u>
Johanna Hageback – MFS-student
Jenny Sundberg – MFS-student
Elisabeth Simelton – New PhD student. Related subject to our project

App 2.

Minutes from the China-seminar 12 September 2002-09-12 Ågrenska villan, Göteborg, Sweden.

Participants: Deliang Chen, Xie Yun,Youmin Chen, Madelene Ostwald, Per Knutsson, Sara Brogaard, Elisabeth Simelton, Johanna Hageback, Jenny Sundberg

1. **Deliang gave a resumé from the trip to China in May**: Deliang, Madelene and Per visited Geography Department (CAS), that gave a presentation or mini workshop – lots of work had been done in Ansai and especially they had lots of work regarding satellite data/remote sensing. We also visited START, Prof. Fu. Same mini-workshop and presentation was done there. While in the field area, Ansai, we collected a lot of data, climate data, interviews etc.

- Deliang showed a power-point presentation of Geography Department (CAS) and Deliang's idea. Regional assessment: IPCC's regional assessment is too big. 152 stations were used. EOF analysis showed the dominant pattern of the climate. CCA analysis good for correlation between two field plus what area is giving the highest variability. The Ansai area showed the strongest linkage to the large-scale climate. Classification problem was presentation on temperature and precipitation – new question: Where is the boundary of the south-western monsoon in China? Something for Yun, Deliang and Youmin to do the coming weeks.
- Chinese student's work was presented since it was done in the Ansai area. Ecological regionalization of China, pattern of precipitation and temperature.

2. **Johanna and Jenny – MFS study in Danangou spring of 2002**: Famers' perception, land use and climate – the climate's influence on local scale land use in the Loess Plateau, China'. Discussion: Lease/rent of land (waste, forest and agriculture), propaganda-influence.

3. **Climate team, Youmin:** 'Precipitation expanded downscaling and its result application to HBV hydrological model in a single catchment'. A method that keeps the extreme events and also keeps the modelled spatial variability to the observed data. Temperature is always easier in downscaling than rainfall, therefore the results looks better. This could be applied to the project area. Discussion: Relation between rainfall and flooding – hydrological data can be very important to what farmer's perceive. The method can be used in the Yanhe valley, but does not need to be finished during the project.

4. **Land-use team, Madelene, Sara and Yun**: Not so much progress yet. Two TM data from Deliang that Sara and Yun will look at tomorrow. The help from 'Eurochina' project is still something to expect as soon as the special issue in Catena is published. Sara has ideas about using biomass model 8 x 8 km – linked to hydrology.
   Sara presented herself and her work in Inner Mongolia.

Deliang presented a land-use study by a student from CAS. TM data/topographic. Conclusion is that the cultivated land-use has not changed while forested and grassland has changed. A conclusion is that we should use as much as possible the expertises at CAS regarding the analysis of the landuse changes. Sara and Madelene will look at this point more closely. Sara will discuss the possibility of using the Biomass model to understand the sensitivity of the primary production to climate in the region with Deliang tomorrow.

5. **Social cultural team, Per:** Ideas from our visit. Change from cultural to political in the future. 'Village' as a focal-point unit, even after the 'household responsibility policy'. Also to see changes on the village as a social-cultural unit.
   Discussion: Land as a security as Sara has seen in Inner Mongolia. Election of village leader. Duel leadership - communist and village leader. President of the village did not seem to have that much power. Changes of the reform – projects are given to different areas in very different ways. How do individual work together, if they work together?

6. **New PhD project, Elisabeth:** Past as a MFS-student and work experiences from Vietnam and Spain. Presented her plans for her PhD work. Focus on soil moisture and regional impact (e.g. Shaanxi Province and Beijing Province) with risk-thresholds as an important method.
   Discussion: The problem with historic-data of soil moisture. Researchers are very protective and usually different groups come in and out in a test site according to Yun. Maybe MODIS-data can be used.

7. **Conference and meeting in China March 2003**: Everyone will try to go and look out for places to get money. The International Symposium on Climate Change (ISCC) conference is 31 March – 3 April in Beijing and we will have an internal meeting on the 29 and if needed on the 28 March for more hands-on work. Field work is planned in April after the conference.

8. **Economic report**: Deliang gave a picture of the economic situation – 63% of what applied for was given. Deliang have an idea that salaries should be guaranteed (63% of applied amount) so travel-money is something we should look for other places. Madelene is leaving her salary while Elisabeth will get part of it.

9. **Report idea, Deliang:** The structure was discussed and revised (see attachment). Does China have and impact on the climate? An interesting question that we will not address in the report.

10. **Articles:** <u>*Climate group*</u>
    1. Whole China to give a perspective.
    2. Boundary between the climate zones.

3. Integrated paper for AMBIO.
4. Chinese journal (Yun thinks methodological paper on Jenny and Johannas work as well as the result). This will be done by Delaing and Yun.
5. International journal on Johanna and Jenny's work.

Yun would like to have a deeper analysis on what drives land-use change – climate or policy.

Lan- use group

1. Aerial photography (have to be done in China – MFS)
2. TM data (lots have been done)
3. NOAA – NDVI over larger area over time
4. Biomass model – Gross primary production (GPP) large scale 8 x 8 pixels * (Sara gave a short presentation) used for production scenario. Sara will give Deliang a list of needed data, he will look into possibility to get it and then Sara will say if it works.
5. Local land-use over the five years (in collaboration with Liding Chen)

Discussion: *What do you do with run-off ? In modelling we don't care. It is not even included in GCM.

Socio cultural group

1. Based on group interviews the question posed is 'how important is the climate to these land users'. Almost ready by Per, Yun and Madelene.
2. Johanna and Jenny's work
3. Hillslope agriculture or off-farm work? / Implication of the tree plantation policy?

Discussion: Johanna thinks that the five last years can give an answer to the question of what is climate driven or policy driven.

We agreed to start writing of the report after the China conference. Until then we'll mainly focusing on a number of articles based on the ideas listed above. However, lead authors for each chapter of the report have been assigned. The idea is that everybody can start preparing the final report.

11. **Integration of results – Multi-Attribute Utility Theory MAUT, Per:** Illustration of what could be done. Based on Embedded case study method by Roland Scholz. It is based on possible scenarios where we can develop different scenarios and variants, which can be developed into a matrix. You can place it on different ambition-levels; scientific, external (ask the farmers – really hard according to Per), intuitive or a combination. Assumptions have to be made.
Discussion: How to define and weight the scenarios and their effect? Deliang talks about sensitivity in the system or even optimize different scenario. It can be difficult but it can be an interesting process.

Practically we have to start with scenario and defining variants. Per, Madelene, Yun and Deliang will sit down before the end of October to schedule the work that will be email-based to start with.