

AGRI-ENVIRO INFORMATION SYSTEM FOR THE NORTH CHINA PLAIN

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ABSTRACT:

The Sino-German Project between the China Agricultural University and the University of Hohenheim, Germany, focuses on sustainable Agriculture in the North China Plain (NCP). One major focus of the project is the establishment of an experiment field near Beijing to investigate different agricultural practices and their impact on yield and environment. The second task is to set-up an Agricultural Environmental Information System (AEIS) for the NCP, which exceeds almost the size of Germany. Researchers from several departments are involved in the project: Agricultural Economics, Agricultural Informatics, Vegetable Science, Landscape Ecology, Phytomedicine, Plant Nutrition, Plant Production and Soil Science. The major aim of the AEIS for the NCP is to provide information (i) about agriculture in the region, (ii) about the impact of agricultural practices on the environment and (iii) of simulation scenarios of sustainable strategies. Consequently, the AEIS for the NCP provides information for decision support and therefore could be regarded as a Decision Support System (DSS), too. The investigation of agricultural and environmental issues have a spatial relation which demands the handling and analysis of spatial data. The use of GIS enables the input, storage, analysis and presentation of spatial data. Therefore, GIS is the major tool for the set-up of the AEIS for the NCP. This contribution discusses the problems of the set-up and presents the design and first results of the AEIS for the NCP.

1. INTRODUCTION

The Sino-German Project between the China Agricultural University and the University of Hohenheim, Germany started three and a half years ago and is located in Beijing. The focus of the project is on sustainable agriculture in the North China Plain (NCP). Sustainable agriculture is a big issue in China (Tso et al. 1998). One major focus of the project is the establishment of an experiment field near Beijing to investigate different agricultural practices and their impact on yield and environment. Investigated crops and vegetables are winter wheat, summer maize, spinach and cauliflower. For the crops, three factors are considered in the different treatments. There are three irrigation treatments (sub-optimal, conventional, optimal), three N-fertilizer treatments (sub-optimal, conventional, optimal), and two treatments of crop residues (with and without residues). For the vegetables, two irrigation treatments (conventional, optimal) and two N-fertilizer treatments (conventional, optimal) are considered. Intensive measurement equipment is installed on the experiment field to collect long term data of soil water, volatilisation, and greenhouse gases. Plant and root data were sampled as well to provide all necessary data for intensive modelling evaluation and calibration. Additional investigations about pesticide, herbicide and fungicide applications have been carried out on the experiment field and in the outer Beijing area. Questionnaires were used to collect information about agricultural practices and the economical situation of the farmers as well. Finally, plant and animal monitoring and mapping were done to investigate the biodiversity in the Beijing area and in the nearby mountains. For more information about

the project and the people involved visit the project homepage (<http://www.uni-hohenheim.de/chinaproject>).

Apart from the field experiment and, the second task is to set-up an Agricultural Environmental Information System (AEIS) for the NCP, which exceeds almost the size of Germany. In the sense of Bill (1999) an Environmental Information System (EIS) is an extended GIS for the description of the state of the environment referring to critical impacts and loads. An EIS serves for the capture, storage, analysis and presentation of spatial, temporal and attribute data and provides basics for measures for environmental protection. Consequently, the AEIS for the NCP provides information for decision support and therefore could be regarded as a Decision Support System (DSS), too. The major aims of the AEIS for the NCP are to provide information (i) about agriculture in the region, (ii) about the impact of agricultural practices on the environment and (iii) of simulation scenarios for sustainable strategies.

The establishment of an AEIS faces three major problems:

- The availability of appropriate spatial and statistical data.
- The development and application of methods and models for regional spatial analysis.
- The development of a user interface which ensures easy access to the spatial information of the AEIS.

Fig.1 shows the provinces which have an area in the NCP. The provinces are Anhui, Beijing, Hebei, Henan, Jiangsu, Shandong and Tianjin. The total area of the seven provinces covers around 780,000 km². The thick black line describes the geographical

border of the NCP. The NCP covers an area of around 328,000 km². In comparison, the size of Germany is around 357,000 km². A problem not yet solved is the definition of the NCP. While in western literature the NCP is described as in Fig.2, in Chinese literature the NCP is much smaller and extends only to the Yellow River. In Chinese literature, the area of the NCP described in Fig.2 is defined as HHH-Plain. The three H's stand for the three rivers which characterize the region. The rivers are Haihe, Huanghe (Yellow River), Huaihe (which represents the south border of the NCP in Fig.1).

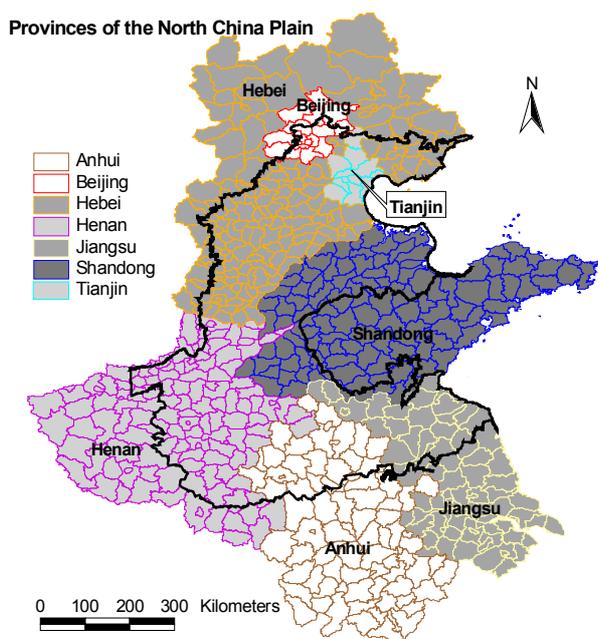


Figure 1. Provinces and geographical boundary of the NCP

2. SET UP OF THE AEIS

The establishment of an AEIS for the simulation of sustainable scenarios means the set up of an extensive geo and attribute database. Especially the modelling of the C- and N-cycles in agro-ecosystems requires numerous input parameters like pH, soil texture, fertiliser N-Input, animal waste input, use of irrigation water, dates of sowing and harvest, yield, etc.. In general, data about climate, soils, land use, and agricultural management are necessary and must be available in the AEIS. Furthermore, methods and models for data analysis and data presentation must be available, too. Therefore, the methodological set up of an AEIS can be described as in Fig.2.

Fig.2 describes the elements of an AEIS. Due to the definition of an EIS and the defined aims of the AEIS for the NCP, an AEIS for sustainable agriculture includes five different information systems which are:

- Base Geo Data Information system (BGDIS)
- Soil Information System (SIS)
- Climate Information system (CIS)
- Land Use Information system (LUIS)
- Agricultural Management Information System (AMIS)

Most important for the spatial matching of all data in the AEIS is the integration of an BGDIS (compare Fig.2). The best solution is the use of an available information system from

official sources like the national bureaus for surveying and mapping. The BGDIS should provide topographical data, elevation lines or a Digital Elevation Model (DEM) and an administrative boundary data set. If such data are not available, the establishment of a BGDIS is necessary. For this task, digitisation of topographical maps and/or GPS surveys are standard methods.

The SIS is essential for providing soil parameters for the agro-ecosystem modelling. Therefore, the SIS has to include (i) spatial soil information in form of maps and (ii) a detailed description of the soil types including soil genesis, physical and chemical soil properties (compare Fig.2). In case soil maps are not available, surveys have to be carried out or methods of computed soil map genesis can be applied. In case of availability of soil maps but lacking detailed soil type description, expert knowledge can be used to generalize typical soil properties.

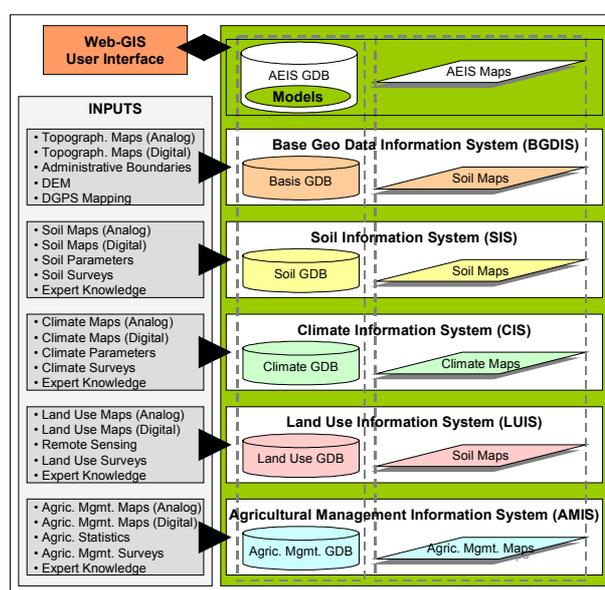


Figure 2. Elements of an Agri-Enviro-Information-System (AEIS)

The CIS provides the necessary climate information (compare Fig.2). Available climate maps can be digitised if there are no digital data available. If this data is not available, climate maps can be generated from point data using GIS interpolation methods. Additionally, climate information could be collected from project weather stations. In general, the availability and accessibility of weather data are good.

Land use data should be provided by a LUIS (compare Fig.2). Usually, land use maps are available, but they lack the necessary information level. In official land use maps it is common that agricultural land use is differentiated between grassland and arable land. For detailed agro-ecosystem modelling, this information resolution is rather poor. Detailed land use maps which provide detailed information about the major crops are necessary. The analysis of multispectral, hyperspectral and/or radar data from satellite or airborne sensor is a standard method to retrieve such kind of information.

Finally, the AMIS is a crucial part (compare Fig.2). For the agro-ecosystem modelling farm management data like fertiliser

N-Input, animal waste input, use of irrigation water, dates of sowing and harvest, yield, etc. are a must. The availability of this kind of information is rather poor. Working on a regional scale, it is usually not possible to set up a spatial database which provides this information for all fields of the farmers in the region. Therefore, this kind of information has to be generated using results from farmers' questionnaires, from field surveys, from agricultural statistical data and from expert knowledge. Using all these sources, it should be possible to define typical farm management for distinct crops in a region. Of course, this generalisation contains an aggregation error.

The AEIS is the sum of the described information systems. They are linked to each other using GIS technologies. Additionally, models and methods for data analysis have to be integrated in the AEIS (compare Fig.2). It is possible to link or even integrate complex agro-ecosystem models into GIS (Bareth and Huber, 2002) and consequently into the AEIS as well. The selection of the methods and models which are integrated into the AEIS has a further important impact on the set up of the geo and attribute database. The methods and models require distinct input parameters. Therefore, the first step of setting up an AEIS is the selection of the methods and models which are integrated in the AEIS later. The methods and models define the data demand.

The availability of and the access to digital geodata is a key issue in macro, meso and micro scale GIS modelling of environmental issues. While it is still possible to collect necessary geodata with a limited amount of time and money for macro scale, it is essential to have secondary sources for meso and micro scales. In China, it is very difficult to obtain information about available geodata and data in general and for foreigners especially due to the data policy. Normally, outside of China there are still only 1:1,000,000 data or smaller ones available. For more information about small scale data check out the links on our China data link page http://www.uni-hohenheim.de/chinaproject/map_links.htm. For modelling environmental issues on meso and macro levels, these kinds of available data are useless.

In general, information about the data quality is lacking in China. But the knowledge of data quality is essential. "If data quality is an important property of almost all geographical data, then it must affect the decisions made with those data. In general, the poorer the quality of the data, the poorer the decision. Bad decisions can have severe consequences." (Longley et al. 1999).

In China, there is no central office responsible to provide information about geodata availability. Some responsibilities are distributed on hierarchal administrative units. The knowledge of available data is stored by several departments and institutes which do not share this kind of information with the public. This counts for statistical data as well. Only some insiders have a general overview of available geodata and how and where to get them.

On national level, the Institute of Geomatics in Beijing is responsible for topographical data. In 1999, they finished the digital topographical database on the scale 1:250,000 (DTD250) in vector format. They provide the data as ArcInfo coverages and many other GIS formats. The data set includes separate files for rivers, lakes, roads, railways, cities, one degree net, 50 m contour lines and administrative boundaries (counties, districts, provinces). The layers were digitized from the topographical

maps on the same scale. The dates of the maps range from the early to the late eighties. The lake polygons are not provided as a layer and were created using the attribute information of the river arcs. A DEM, generated from the contour lines, is available, too. Topographical data on a larger scale e.g. 1:50,000 are available for some areas as scanned raster data. Data on a scale 1:10,000 or larger are not available from a national office. Therefore, county, district and province surveying bureaus are responsible and have to be contacted directly for any data deliveries. Data of 1:10,000 and larger ones are not publicly accessible in China. A special authorization is needed to obtain access. The National Institute of Geomatics in Beijing started a national project in co-operation with the province bureaus of surveying and mapping to set up the digital topographical database 1:10,000 which is available for important economic areas already.

Digital land use data are available on the scales 1:250,000 and 1:100,000 in ArcInfo vector format, too. The land use data derive from LandsatTM land use classifications. The Institute of Remote Sensing of the China Academy of Sciences in Beijing is responsible for the land use classifications. On the internet, there is some information about the whole project available (<http://crers.irsas.ac.cn/english/index.htm>). The National Land Resources and Environment Warehouse is accessible via this page as well. On the data warehouse web page it is only possible to get a preview of the land use data on a scale of 1:250,000 or smaller. For the data 1:100,000 it is not possible, yet, neither for some other links which are under construction. The 1:100,000 land use data are classified in the same land use classes as the 1:250,000 data and are just a little more detailed in spatial resolution. The land use classes are further described for mountains, hills, plains and very steep areas. More detailed land use data sometimes exist at governmental bureaus like the agricultural bureaus on province or county levels or at the Bureau for Land Resource Management. For Beijing, the agricultural bureau set up a land use database to evaluate structural and land use changes. These kinds of data are not public, either.

Compared to the availability and the access of topographical and land use data, soil data are much more difficult to get. Therefore, some useful information about digital micro scale data sources is provided. The FAO distributes the digital soil map of the world in 1:5,000,000 (<http://www.fao.org/ag/agl/gll/smw.htm>). On the same scale, the FAO provides a soil and physiographic database for northern and central Eurasia (http://www.fao.org/catalog/book_review/giii/x3528-e.htm) which covers China, too. In China, there are no official digital soil data available. The Institute of Soil Sciences of the Chinese Academy of Science in Nanjing is coordinating the establishment of a soil information system which is still in development. Soil maps in meso and macro are not accessible by a national office, either. Soil maps on a scale between 1:200,000 and 1:300,000 are available from the province authorities and cover counties or districts. For some provinces, e.g. Hebei, there is even a soil atlas available which contains the soil maps for each county on a scale of 1:100,000 to 1:300,000 depending on the size of the counties. At the agricultural bureaus macro scale data are existent, but usually not publicly obtainable. On a scale of 1:10,000, the agricultural bureaus set up a soil and land use map which exists in digital format for some provinces, e.g. Beijing. These are no public data and are usually only for governmental uses.

The China statistical yearbook is for purchase on province level and is available from the statistical bureaus in China or from the China Data Centre at the University of Michigan. For more information about accessible statistical data of China, check out the page of the China Data Centre (<http://www.umich.edu/~iinet/chinadata/>). More detailed data, e.g. for agriculture, are provided by the Ministry of Agriculture and can be purchased from the bookshops of the Ministry. The Agricultural Statistical Yearbook is on province level. More detailed data are provided in the provincial statistics, which are on county level. In these statistics, there are still some data very aggregated and not useful for GIS applications. More detailed statistical data are sometimes available from statistical bureaus themselves and they have to be contacted directly. Finally the province bureaus for agriculture have extensive data and knowledge about the farm management in the area for which they are responsible. This source is a key issue for the set up of the AMIS.

Long term climate data exist for several hundred stations covering all of China. These data are not public and are not available in digitised format. International climate data providers also offer long term data which are easy to get.

In Fig.3 some spatial data in the AEIS for the NCP are shown for Hebei District which is located in the far south of Hebei Province. The cities, villages, railways, roads, rivers, contour lines and administrative borders derive from the official digital topographical database 1:250,000. The colored polygons represent the soils of a digitized soil map on a scale 1:200,000. The white polygon outlines show without representing attribute properties the digital land use map on a scale 1:250,000.

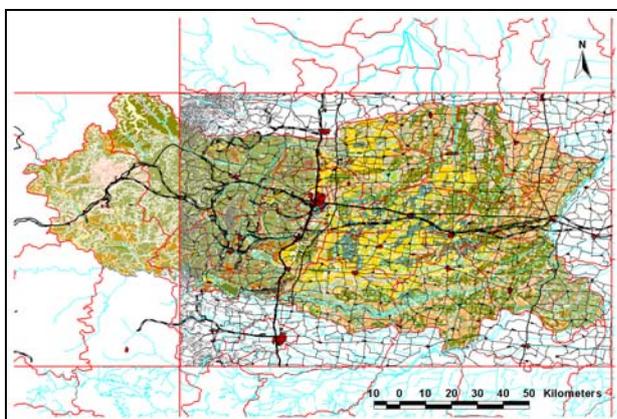


Figure 3. Selected spatial data in the AEIS for the NCP

3. RESULTS

According to the described aims of the AEIS for the NCP to provide information (i) about agriculture in the region, (ii) about the impact of agricultural practices on the environment and (iii) of simulation scenarios for sustainable strategies, first results can be presented. For example to provide information about agriculture in the NCP, agricultural statistical data were customized by the Agricultural Statistical Bureau. The data are from 1995 and provide agricultural data on county level. The agricultural statistic data from 1995 is integrated in the AEIS for the NCP and the data and some basic analysis of the data can be displayed as maps to show spatial distribution.

Fig.4, Fig.5, and Fig.6 show the spatial distribution of the major field crops in the NCP. In Fig.4, the sown area of wheat is shown in percentage of the total sown area (TSA). The percentage of wheat of the TSA in the NCP ranges from 0 to 50%. The mean value for the NCP is 35%. It is clearly visible in Fig.4 that the cultivation of wheat is highest in the centre of the NCP while in the far NE and far SE the part of wheat of the TSA is lowest.

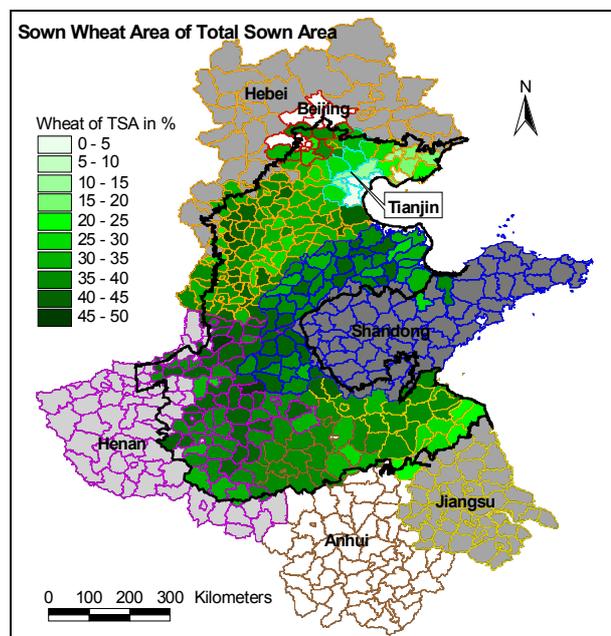


Figure 4. Part of sown wheat area of the TSA for 1995

Besides wheat, the other major crop is maize (Fig.5). Especially in the northern part of the NCP, the percentage of maize of the TSA ranges between 15 and 45%. The percentage of maize of the TSA in the NCP ranges from 1 to 45%. The mean value for the NCP is 22%. In the NCP, maize is usually cultivated in rotation with wheat. The rotation is winter wheat (sown in autumn) and summer maize (sown in early summer). The sum of the mean values of wheat and maize for the NCP is 57%. Therefore, the winter wheat and summer maize rotation is the predominant agricultural land use pattern in the NCP. In Fig.6, the sown area of this rotation is shown in percentage of the TSA. The percentage of winter wheat and summer maize rotation of the TSA in the NCP ranges from 1 to 84%. Particularly, those counties where rice cultivation is predominant have values smaller than 45%. Fig.6 clearly describes the importance of the winter wheat and summer maize rotation in the NCP.

Further information which is provided in the agricultural statistical data are fertilizer data. Fig.7 shows the annual N-fertilizer input per ha arable land. The N-fertilizer input for the counties of the NCP ranges from 76 to 726 kg N ha⁻¹yr⁻¹. The mean N-fertilizer input for the NCP is 266 kg N ha⁻¹yr⁻¹. An explanation for the small values in the eastern part of Hebei Province cannot be given and need further investigations. Another problem is the unknown method of data collection. For example, it is not known if the N-fertilizer amount is calculated by the amount of farms located in the county or if it is calculated from the real input on arable land in the county. If it is calculated by farms which are located in the county it is

possible that the area of arable land of the farms is larger than the area of arable land of the counties, in case the farms cultivating land outside the county. Such issues need further investigations, too.

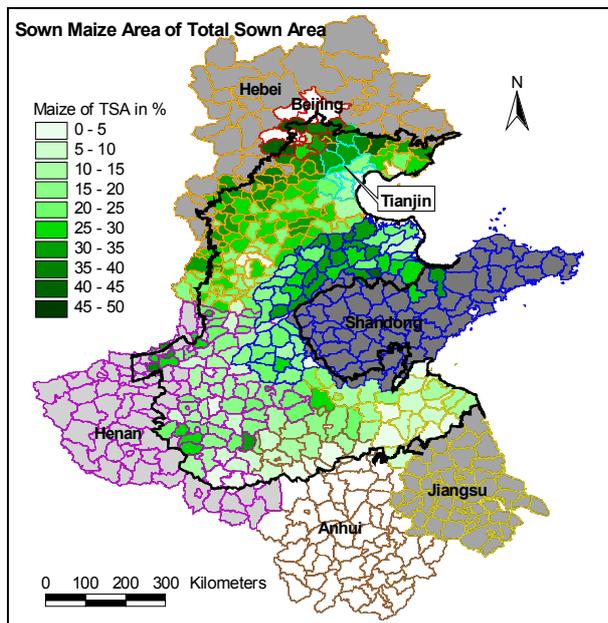


Figure 5. Part of sown maize area of the TSA for 1995

animal excretion is exceptionally high, too. For calculation for animal excretion, international standard factors were used (IPCC 1996). The N excretion from animal production per ha arable land in the NCP ranges from 0 to 810 kg/ha. The mean N excretion from animal production per ha arable land for the NCP is 174 kg/ha. In this calculation, no N-losses are considered. Comparing Fig.7 and Fig.8, it is obvious, that there are some counties which have exceptionally high N-inputs from N-fertilizer and animal waste. But it is not clear how much of the animal waste is used as organic fertilizer at all. Therefore, it is not possible to sum the N-input from mineral and organic fertilizer for total N-input per ha arable land.

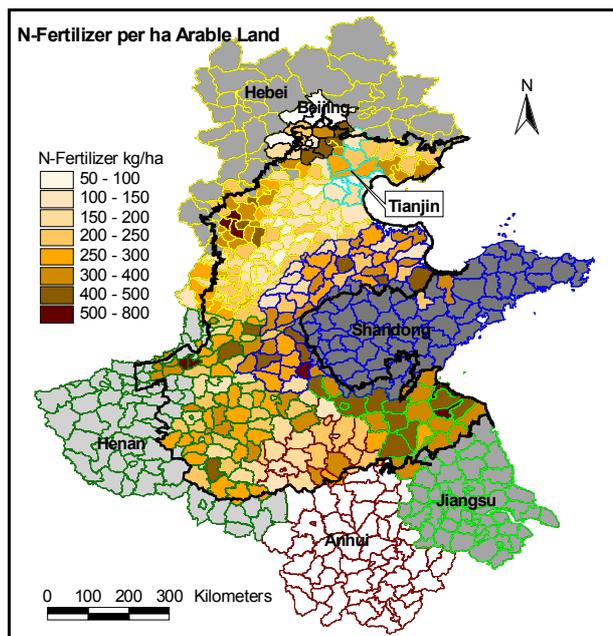


Figure 7. Applied N-fertilizer per ha arable land for 1995

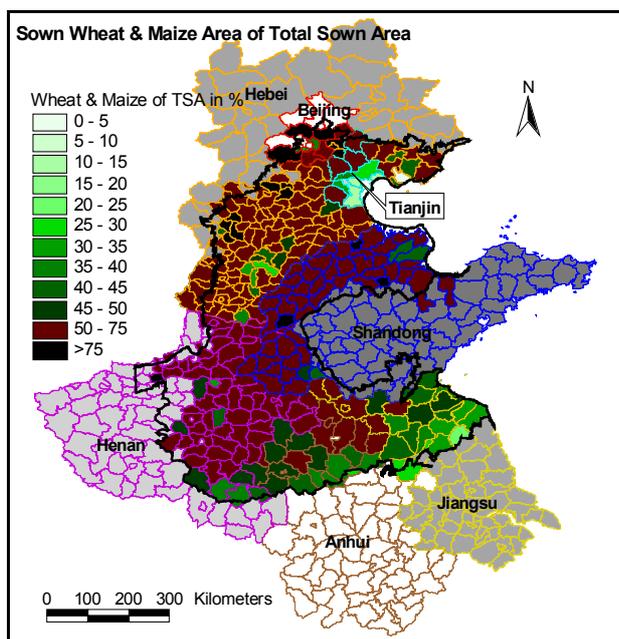


Figure 6. Part of sown wheat & maize area of the TSA for 1995

The calculation of the animal units (AU) per ha from the agricultural county data for 1995 are shown in Fig.8. The AU per ha for the counties of the NCP ranges from 0.3 to 9.2. The mean value for the NCP is 2.7 AU/ha. While in Hebei and Jiangsu Provinces the AU/ha are comparably low, in the other Provinces most counties show values between 3 and 7.5 AU/ha. These are exceptionally high values, which derives mainly from the large amount of fattening pigs in these counties. Consequently, the calculated amount of produced N from

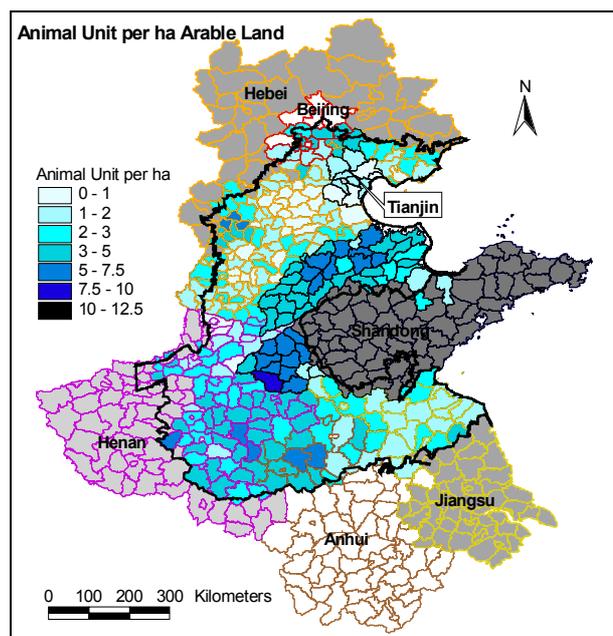


Figure 8. Calculated AU per ha arable land for 1995

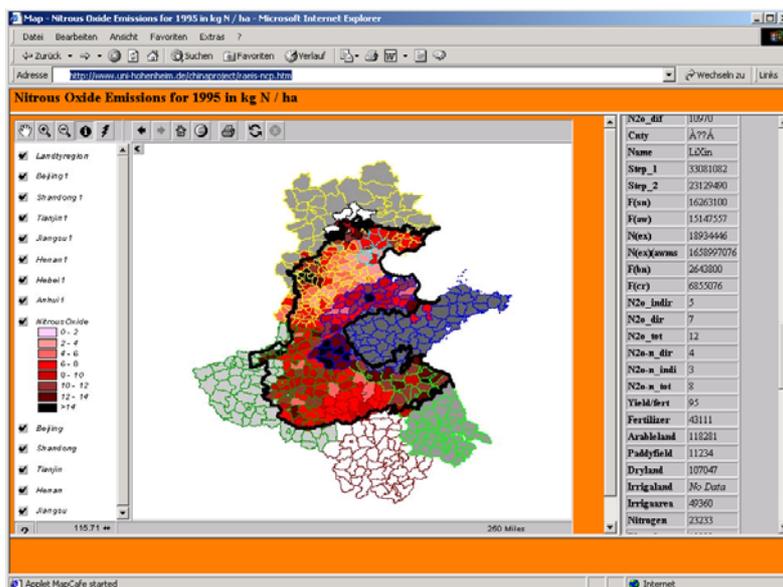


Figure 9. First WebGIS interface of the AEIS for the NCP

In general, the analysis and interpretation of statistical data is a central task. Various statistical, empirical and knowledge based methods are used for analysis. In this contribution, the INTERGOVERN PANEL ON CLIMATE CHANGE method (IPCC 1996) for the calculation of greenhouse gas emissions from agriculture is used as an example for data analysis and for the production of new data from a set of agricultural statistical data. The IPCC method uses defined factors which are multiplied with statistical data for emission calculations. Methods like the IPCC method are described by van Breemen und Feijtel (1990) as bookkeeping methods. The IPCC method is a comprehensive method to calculate national greenhouse gas inventories. This method is used to calculate N_2O emissions on county level of the NCP. The IPCC method differentiates between direct and indirect N_2O emissions. Direct N_2O emissions are the emissions from agricultural soils and from animal production. Indirect N_2O emissions result from nitrogen leaching and runoff. The results of the calculation of the total N_2O emissions for the counties of the NCP by using the IPCC method are visualized in Fig.9. The total N_2O emissions are the sum of the direct and indirect N_2O emissions. Direct N_2O emissions are the emissions from agricultural soils and from animal production. Indirect N_2O emissions result from nitrogen leaching and runoff. The direct N_2O emissions on county level for the NCP ranges from 2 to 24 kg $N_2O-N ha^{-1}yr^{-1}$. The mean for the NCP is 9 kg $N_2O-N ha^{-1}yr^{-1}$.

Fig.9 also displays the first WebGIS user interface for the AEIS for the NCP (compare also Fig.2). All data of the AEIS could be presented like this. Due to data policy this is not yet possible and therefore the WebGIS interface has until now only been a restricted trial version. But it could be immediately made accessible to the public. For further interface development, the latest ArcGIS software packages will be used.

4. CONCLUSIONS

Using GIS and RS technologies it is possible to set up a regional AEIS which allows spatial modelling. The set up of an AEIS enables (i) the extensive modelling of the impact of agriculture on the environment, (ii) the creation of modelled simulation scenarios considering sustainable strategies in agriculture, and (iii) the presentation of the whole data set. From the experience of the set up of an AEIS for the NCP three major difficulties can be defined:

- Availability of detailed soil parameters
- Availability of detailed land use maps
- Availability of detailed farm management data

GIS and knowledge based method can be used to generate that kind of data. The whole process of the set up of an AEIS for a larger area is complex and needs interdisciplinary cooperation.

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