REGIONALIZATION OF N$_2$O MEASUREMENTS 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, focused on sustainable Agriculture in the North China Plain. One major focus of the project was the establishment of an experiment field near Beijing to investigate different agricultural practices and their impact on yield and environment. The second task was to set-up a GIS based Agricultural Environmental Information System (AEIS) for the North China Plain (NCP), which exceeds almost the size of Germany. Researchers from several departments were involved in the project: Agricultural Economics, Agricultural Informatics, Vegetable Science, Landscape Ecology, Phyto medicine, 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 for 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. In this contribution, the focus is on the importance of the linkage of measurement data with spatial data for a selected area of Beijing municipality which is a part of the North China Plain. By using the database of the AEIS, it is possible to roughly estimate the N$_2$O emission from winter wheat / summer maize rotation which is the dominant crop rotation in the North China Plain. Furthermore, the potential of some mitigation strategies can be estimated for the regarded area. Finally, the comparison with and evaluation of available models and methods (IPCC; DNDC) for regional calculation is presented.

INTRODUCTION

The Sino-German Project between the China Agricultural University and the University of Hohenheim, Germany started in November 1998 for 4½ years and was located in Beijing. The focus of the project was on sustainable agriculture in the North China Plain (NCP). Sustainable agriculture is a big issue in China. One major focus of the project was the establishment of an experiment field near Beijing to investigate different agricultural practices and their impact on yield and environment. Investigated crops and vegetables were winter wheat, summer maize, spinach and cauliflower. For the crops, three factors were considered in the different treatments. There were 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) were considered. Intensive measurement equipment was 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 modeling 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. Finally, plant and animal monitoring and mapping were done to investigate the biodiversity in the study region.

Apart from the field experiment, the second task was 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 objectives 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.

Figure 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 Figure 1, 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 Figure 1 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 Figure 1).

Figure 1: Provinces and geographical boundary of the NCP.

SET UP OF AN 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 modeling of the C- and N-cycles
Regionalization of $\text{N}_2\text{O}$ measurements for the North China Plain

in agro-ecosystems requires numerous input parameters like pH, soil texture, fertilizer N-Input, animal waste input, use of irrigation water, dates of sowing and harvest, yield, etc. According to Bareth and Yu (2002), Figure 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)

![Figure 2: Elements of an Agri-Enviro-Information-System (AEIS) (Bareth and Yu, 2002).](image)

Most important for the spatial matching of all data in the AEIS is the integration of an BGDIS (compare Figure 2). The BGDIS should provide topographical data, elevation lines or a Digital Elevation Model (DEM) and an administrative boundary data set. The SIS is essential for providing soil parameters for the agro-ecosystem modeling. 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 Figure 2). The CIS provides the necessary climate/weather information (compare Figure 2). Climate/weather maps can be generated from point data using GIS interpolation methods. Land use data should be provided by a LUIS (compare Figure 2). Detailed land use information on crops should be stored in the LUIS. For detailed agro-ecosystem modeling, the information level in available land use maps is rather poor. 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 Figure 2). For the agro-ecosystem modeling farm management data like fertilizer N-Input, animal waste input, use of irrigation water, dates of sowing and harvest, yield, etc. are a must. 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 Figure 2). It is possible to link or even integrate
complex agro-ecosystem models into GIS (Bareth and Huber, 2002) and consequently into the AEIS.

The availability of and the access to digital geodata is a key issue in macro, meso and micro scale GIS modeling 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.

N₂O MEASUREMENT

Two automatic systems for measuring gas fluxes have been developed. One for the measurement of N₂O- and CH₄-fluxes of soils and one for the measurement of NH₃-volatilization. The system is described in the Manual “Automatic Systems for the Measurement of N₂O-, CH₄- and NH₃-Gas Fluxes” in detail (Kogge, 2003 unpublished).

The N₂O- and CH₄-fluxes in winter wheat and summer maize rotation have been measured with the 9 main measuring chambers (three replicates per plot) (Figure 3), which are adaptable in height from 0.25 m to 2.25 m and cover a soil area of 1.4 m x 1.4 m (1.96 m²), respectively, for the following three treatments of winter wheat/summer maize experiment:

- conventional irrigation and conventional N-fertilisation
- conventional irrigation and optimised N-fertilisation
- optimised irrigation and optimised N-fertilisation.

![Figure 3: Automated closed chambers to measure N₂O emissions from winter wheat (left) and summer maize (right).](image)

SOIL-LAND-USE-SYSTEM APPROACH

The method for the regionalization of measurement data and expert knowledge is based on the soil-land-use-system approach (SLUSA) (Bareth et al., 2001). The SLUSA is based on the ecosystem approach described by Matson and Vitousek (1990). This ecosystem
Regionalization of $N_2O$ measurements for the North China Plain

The approach was furthermore disaggregated in order to estimate and visualize the greenhouse gas emissions (CH$_4$, CO$_2$, N$_2$O) from agricultural soils for a distinct region (Bareth and Doluschitz, 2003). The disaggregation of the ecosystem approach was undertaken by using GIS technologies. The SLUSA is a GIS and knowledge based approach for environmental modeling.

In Figure 4, the method of the SLUSA is shown. The first step is the set up of a GIS which contains relevant data. In the second step, GIS tools are used to overlay climate, soil, land use, topography, farm management, and other data like preserved areas or biotope (if available). This procedure is the basis for the spatial related identification of different soil-land-use-systems. In the third step, emission data and process knowledge of the region of interest as well as from literature are linked to these systems. For the linkage $N_2O$ emission potential classes are created and knowledge based production rules are programmed. The latter ones are commonly used to generate new knowledge from expertise in knowledge based systems like expert systems. Available data from the region of interest are considered with higher priority. Finally, GIS software tools are used in the fourth step to visualize and to quantify the generated emission data. The quantitative emission estimation is done by multiplying the areas of each $N_2O$ emission potential class with the representative value of each class. The new spatial emission data can be integrated into other regional models like regional farm models.

![Soil-Land-Use-System Approach (SLUSA)](image)

Figure 4: Soil-land-use-system approach (SLUSA) (Bareth et al. 2001).

**AEIS FOR BEIJING MUNICIPALITY**

According to the presented structure of an AEIS in Figure 2, the available data for the AEIS for Beijing Municipality is described in the following paragraphs. Due to data policy, spatial data in a scale larger than 1:100,000 were not accessible.

For the establishment of a BGDIS, it was possible to obtain data of the national digital topographic database 1:250,000. In this database, vector data for rivers, lakes, roads etc. is available. Some of these data are shown in Figure 5. Additionally, DGPS surveys were carried out in the study region to collect ground control points and training fields for a supervised satellite image classification.
Digital soil data larger than 1:1,000,000 are not available in China or for Beijing Municipality. Therefore, a soil map of the study region in a scale 1:200,000 was digitized by using the data of the BGDIS for calibration. The data is shown in Figure 6.

Figure 5: Topographic and land use data of the AEIS for Beijing Municipality.

Figure 6: Digitized soil map for Beijing Municipality.

The climate information system contains data of the project weather station in Dongbeiwang. Consequently, detailed weather data on daily basis is included in the AEIS.

For the land use information system, official land use data in a scale 1:100,000 were obtained. The differentiation of agricultural land is not satisfying in this database. Therefore, the results of an supervised classification of a Landsat scene were incorporated into the official land use data. This procedure is described in Figure 7 for winter wheat and the results are shown in Figure 8.
The information in the AEIS about agricultural management derives from the field experiment in Dongbeiwang and from a farm survey in the study region. Information about conventional management and optimized management strategies are stored in the AMIS.

The AEIS stores all data to model and/or regionalize the emission of nitrous oxide from arable land in the part of Beijing Municipality which belongs to the North China Plain. Based on the methodology of the SLUSA it is possible to select all polygons in the database of the AEIS which are cultivated with winter wheat/summer maize and have similar soil attributes as the research site in Dongbeiwang. Consequently, the results of the measurements can be linked to the database in a first step. In a second step the calculation of the total emissions of the selected area can be done. These results are listed in Table 1.

Table 1: Nitrous oxide emissions from selected winter wheat/summer maize area of the North China Plain within Beijing Municipality.

<table>
<thead>
<tr>
<th>Year</th>
<th>N₂O (conventional) (t N yr⁻¹)</th>
<th>N₂O (optimized) (t N yr⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>266</td>
<td>122</td>
</tr>
<tr>
<td>2001</td>
<td>230</td>
<td>109</td>
</tr>
</tbody>
</table>

In Table 1, the results of the regionalization of the measurement data are presented for conventional and optimized management. Latter is the optimization of N-fertilization and
irrigation. The emissions presented in Table 1 are only for selected winter wheat/summer maize areas in the North China Plain of Beijing Municipality. The results show clearly that there is an immense potential to reduce emissions of nitrous oxide from arable land in China.

DISCUSSION AND CONCLUSIONS

In this contribution it is clearly shown that the SLUSA can be used to identify similar soil-land-use-systems within a region. Measurement data for these selected polygons can be added into the attribute database. Consequently, the regionalization of the measurement data is possible using the approach of an GIS-based AEIS.

An disadvantage of the presented methodology is the lack of considering annual dynamics. Therefore, the interfacing of process based models with GIS may be adequate for distinct regional applications. Examples are given e.g by Bareth and Huber (2002), Li et al. (2000), and Hartkamp et al. (1999).

In Table 2, the N$_2$O emissions for the regarded polygons are presented. It is obvious that the process based DNDC model simulates higher emissions than the SLUSA. The IPCC method produces even higher results than DNDC and SLUSA. Because the SLUSA is based on measurement data, the results seems more accurate than the other two approaches.

Table 2: Nitrous oxide emissions from selected winter wheat/summer maize fields of the North China Plain within Beijing Municipality calculated with the DNDC model and the IPCC method.

<table>
<thead>
<tr>
<th>Year</th>
<th>DNDC (N$_2$O t N yr$^{-1}$)</th>
<th>IPCC (N$_2$O t N yr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>452</td>
<td>633</td>
</tr>
<tr>
<td>2001</td>
<td>439</td>
<td>507</td>
</tr>
</tbody>
</table>

REFERENCES


Bareth, G. and Huber, S., 2002: Integration of process based ecological models into GIS. 


