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Application of the land resources information system SLISYS in the Oueme basin of Benin (West Africa)

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Abstract

The objective of the the soil and land resources information system SLISYS for the Oueme basin in Benin and Nigeria is the estimation of long-term evolution of crop yields and of diffuse emissions from agricultural land into water bodies in relation to climate and land use and land management changes.

SLISYS-Oueme was created to provide data about soils, climate and terrain conditions in the Oueme basin. The data domain of SLISYS-Oueme contains soil information based on the SOTER map of Benin, climate information from 133 meteorological stations distributed in the whole country as well as model specific data on crop management. Land cover is derived from a LANDSAT ETM interpretation from the year 2003 (Igue et al. 2006). On the land cover unit “Mosaic of cropland and fallow”, 16 crops as well as fallow land are distinguished considering crop specific management with respect to fertilization, irrigation and length of fallow period. SLISYS-Oueme contains a spatially distributed model for the estimation of diffuse emissions at a high spatial and temporal resolution. The estimation of crop yields for the 16 crops is based on simulations with the agroecosystems model EPIC (Erosion Productivity Impact calculator). The basin has been subdivided into hydrological response units (**L**and **U**se-**S**oil **A**ssociation-**C**limate unit, LUSAC) which are quasi-homogeneous with respect to land use, soil conditions and climate. EPIC calculates the crop yields for each LUSAC unit. The results are then aggregated to the department or subbasin scale according to the area coverage of each LUSAC. As an example for potential applications of SLISYS, calculations of actual crop yields as well as the effects of fallow systems on crop productivity at the department level are presented

Keywords: Land resources, information system, crop production, Benin

1. Introduction

Taking into account the interactions between land use, water demand and water quality is a prerequiste for a true integrated water resources management at the basin scale. The RIVERTWIN project (www.rivertwin.org) developed the basin-scale model ensemble MOSDEW (Müller et al. 2005, Gaiser and Stahr 2006) which covers those processes in land use, hydrology and economy that are essential for the long-term planning of water resources management. The land resources information system SLISYS-Oueme was created to provide data about soils, climate and terrain conditions to the model ensemble in the upper and middle Oueme basin, which has an extension of 49 200 km^2 in the Republic of Benin and Nigeria (West Africa). In addition, it contains a spatially distributed model for the estimation of diffuse emissions and yields of a total of 16 most relevant crops.

2. Material and Methods

SLISYS is a relational database system using MS-ACCESS as user interface (Gaiser et al. 2006). The data domain of SLISYS-Oueme contains soil information based on the SOTER map of Central Benin (Igue al. 2005), climate information from 133 meteorological stations distributed in the whole country. Land cover is derived from a LANDSAT ETM interpretation from the year 2003 (Igue et al. 2005). On the land cover unit “Mosaic of cropland and fallow”, 16 crops as well as fallow land are distinguished. The proportion of each crop was extracted at the department level from the agricultural statistics of the year 2003 (Institut National de Recherches Agricoles du Benin, unpublished). Since the statistics do not distinguish sole and mixed crops, the proportion of mixed cropping was estimated from representative village surveys carried out by the Institut National de Recherches Agricoles du Benin and from the available cropping area per department. It was assumed that only the local maize varieties are used for mixed cropping and that 50% of the local maize area is intercropped with Cassava, Sorghum or Peanut. In the departments Plateau, Atlantique and Oueme, where due to the climatic conditions two maize crops per year are possible, it is assumed that 30% of the area planted with local maize varieties area is under annual maize/maize rotation. After combining the above given assumptions with the cropped area from the statistics, the cultivated area was compared with the land cover unit “Mosaic of cropland and fallow” and the proportion of fallow land per department was determined. For each crop, specific management with respect to growing cycle, fertilization and irrigation is considered.

The informations on soil, climate and land use were gathered and used as input into a spatially distributed model for the estimation of crop yields. The basin has been subdivided previously into 12036 hydrological response units (LUSAC: **L**and **U**se-**S**oil **A**ssociation-**C**limate unit) which are quasi-homogeneous with respect to land use, soil association and climate. Depending on the heterogeneity of land use and soil associations, the area of the LUSAC units ranges between 0.1 and 3000 ha. The estimation of crop yields for the 16 crops is based on simulations with the agroecosystems model EPIC (Erosion Productivity Impact calculator, USDA 1990) for each soil type within the LUSAC units at daily time steps. EPIC is connected to SLISYS through the interface “Interactive EPIC” (http://www.public.iastate.edu/~elvis/i_epic_main.html). The results of the simulations were aggregated to the LUSAC units and then transferred to the database. Within the database, additional processing procedures are aggregating the results to the commune, department or subbasin level according to the area coverage of each LUSAC. Until present, model calibration was carried out at the field level.

3. Results and Discussion

3.1 Comparison of actual and simulated yields

SLISYS simulated crop yields for the period 1980 to 2003 for each LUSAC unit. The simulated crop yields were aggregated to the department level and compared to crop yields given in the official statistics of the Institut National des Recherches Agricoles du Benin (INRAB/PAPA 2005). On average over the period 1987 to 2003 for which statistical data were available, crop yield estimates with SLISYS reached the same level as the statistical yields in most of the departments (Figure 1). The temporal dynamics of the statistical crop yields are generally low, which is well described by the model results for all crops. However, local maxima or minima of crop yields are not in all cases captured by the model results. The reasons for these peaks in the statistics can not be traced back properly, but it is obvious that extreme weather conditions (e.g. droughts in 2001) are not the only factor that determines average crop yields at the department level. Variations in management (proportion of newly cleared cropland or amount of mineral fertilizer applied) may have more impacts on crop yields at the department level than the amount of rainfall and its temporal distribution. Among the 16 crops included in the simulations, yields of yam, cowpea and tomato are in most cases overestimated (Figure 1c). Several reasons are likely to be responsible for the poor performance of SLISYS with these crops: (1) the crop parameter

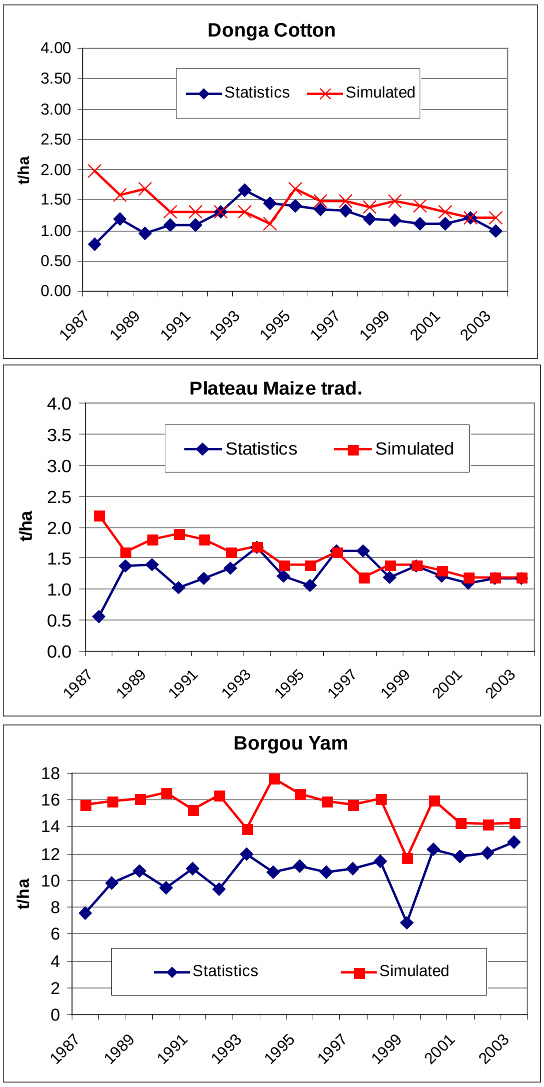

Figure 1: Comparison of simulated crop yields and data from the official statistics for cotton, maize and yam during the period 1987 to 2003

tables in the EPIC programme did not provide physiological parameters for yam and the modified crop parameter table for cassava has been used (2) tomatoes are usually grown on small plots or scattered as single plants in the fields, which may cause errors in the estimation of hectare yields and unreliable statistical data (3) in the dominant rotations, cowpea is usually planted at the end of the cycle after the nutrient levels in the fields have decreased; this crop rotation effect has not yet been considered in the simulations. Hence, further calibration work on developing crop parameter files for yam and the inclusion of crop rotation effects is necessary for certain crops. In addition, the yields of tree crops like Cashew and Mango need also further calibration at the field and regional scale.

3.1 Proportion of cropland and fallow

The proportion of cropland in the departments within the Oueme basin is highly variable. The departments in the Southern part of the basin (Oueme, Plateau and Zou) show lower percentages of fallow land as compared to the departments in the North (Donga, Borgou, Atacora) (Figure 2). This can be explained by the higher population density and the earlier colonisation of the South, where the kingdom of Dahomey was located with its centre in the city of Abomey, the capital of the Zou department.

3.2 Sensitivity of crop yields to the proportion of cropland and fallow

The higher the proportion of cropland in a department, the lower is the share of fallow land. This has serious implications for the fertility of the soils, because the traditional way of fertility restoration is leaving the land under natural regrowth for several years. The higher the proportion of cropland and the lower the proportion of fallow land, the shorter is the fallow period. Since neither manure nor mineral fertilizers are used, except for cotton, the yield levels depend on the

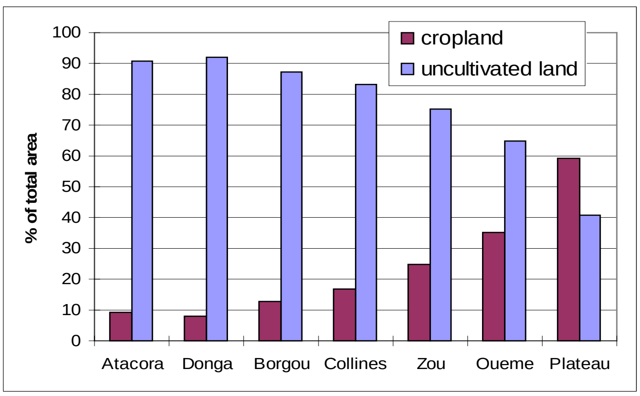

Figure 2: Proportion of cropland (%) in the year 2003 in the different departments of the Oueme basin

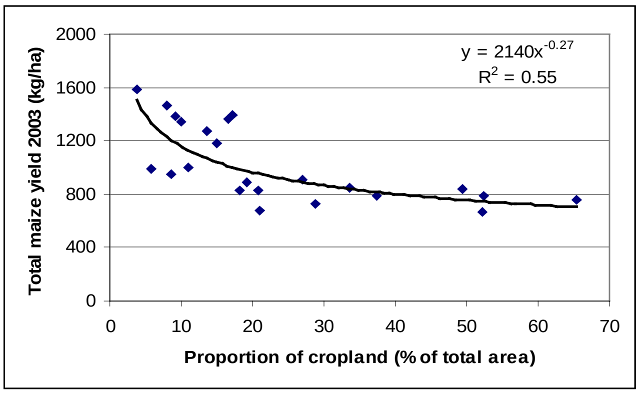

Figure 3: The effect of changing proportions of cropland in different municipalities on maize yields (kg/ha) as reported in the statistics

share of fallow land in each land management or administrative unit. Figure 3 shows the mean maize yields (statistical data of the year 2003) in the municipalities that have a major share in the upper and middle Oueme basin, excluding Parakou which is dominated by settlement area. The maize yields are between 674 kg/ha in the municipality of Zagnando (Zou department) and 1585 kg/ha in the municipality of Bassila (Donga department). The yield level is correlated with the proportion of cropland in each municipality. The higher the share of cropland, the lower is the proportion of fallow land and the maize yield. Maize as a crop with high nutrient demands can be seen as an indicator for the degree of soil fertility restoration.

The land resources information system SLISYS is able to capture the fallow effects on crop yields at the department level by implementing either two or five year crop/fallow rotations into long-term simulations of 30 to 50 years and modify their spatial distribution according to the proportions of fallow land in each administrative unit (department or municipality) (Figure 4). The threshold when crop yields are strongly declining is at a share of 60 to 80% cropland within the land unit crop/fallow mosaic which coincides with the departments of Oueme and Plateau.

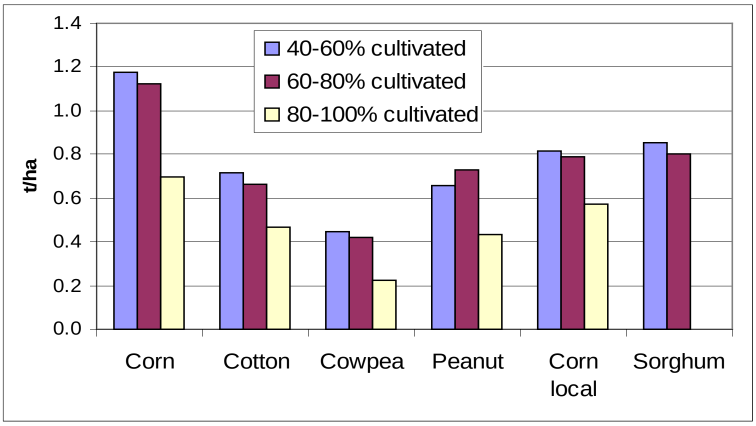

Figure 4: The effect of changing proportions of cropland in the fallow/cropland mosaic unit at the department level on crop yields of six major crops as simulated by SLISYS

4. Conclusion

The land resources information system SLISYS for the upper and middle Oueme basin has the potential to describe adequately crop yield levels at various temporal and spatial resolutions. In particular it is able to capture fallow effects at the regional scale which is an essential feature when longterm strategic planning of water and land resources is to be carried out.

5. Acknowledgements

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References

Gaiser, T. and H. Weippert: Regional estimation of nitrate leaching and ground water pollution with the land resources information system SLISYS-Neckar. World Conference of Soil Science. Philadelphia, USA, 9-15 July 2006 http://crops.confex.com/crops/wc2006/techprogram/ P16879.HTM

Igué A. M. (2005): Soil information system for the Oueme basin. http://www.rivertwin.de/assets/publications/D15_ SLISYS_Oueme basin2.pdf.

INRAB/PAPA (2005): Database on agroeconomic conditions in relation to water availability in the Oueme basin. http://www.rivertwin.de/assets/publications/D17_ECONWAT_deliverable_Oueme_Final_C1.pdf

Müller, M.G., Printz, A. und Schwarz-v.Raumer, H.-G. (2005): MOSDEW – ein Werkzeug zur strategischen Planung im integrierten Wassereinzugsgebiets-Management. In: Strobl, J., Blaschke, T. und Griesebner, G.: Angewandte Geoinformatik 2005. Beiträge zum 17. AGIT-Symposium Salzburg. Wichmann Verlag, Heidelberg, pp 481-486.

USDA (1990): EPIC - Erosion/Productivity Impact Calculator. 1. Model Documentation. U.S. Department of Agriculture. Technical Bulletin No. 1768. Washington D.C., USA. 235 p.