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Development and implementation of an interactive Spatial Decision Support System for decision makers in Benin to evaluate agricultural land resources—Case study: AGROLAND

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ABSTRACT

The sustainable use of agricultural land resources with concern to food security is essential, particularly in developing countries, where yields depend primarily on the biophysical conditions. To support decision making concerning national agricultural land usage, a computer based Spatial Decision Support System (SDSS) was developed. Within this SDSS, named AGROLAND, decision makers are able to visualise and evaluate biophysical agricultural land resources based on a marginality index for agricultural land use (MI). Data derived from remote sensing like MODIS or SRTM are thereby interesting and embolden sources to derive natural constraints. MI is calculated by using a fuzzy logic determination algorithm within the interactive SDSS. In AGROLAND, possibilities of user interactions during runtime as well as advanced model-based raster analyses are implemented to generate MI. This paper explicates (i) the development of AGROLAND for Benin, and (ii) the system implementation in institutions optimizing management strategies on the national scale.

1. Introduction

Spatial Decision Support Systems (SDSSs) contain functionalities of Geographical Information Systems (GIS) and remote sensing (RS). Additionally, they have interfaces available to access and run scientific models, and they use expert knowledge as well as logical decision trees to generate their results (Keenan, 2006; Malczewski, 2006; Laudien and Bareth, 2007). These SDSSs can be used as comprehensive computer based decision support tools for numerous problems in environmental research and management.

The work described in this paper was carried out within the interdisciplinary research project IMPETUS (an integrated approach to the efficient management of scarce water resources in West Africa) (Speth et al., 2005). One major task in the third project phase (2006–2009) was the development, implementation and application of SDSSs for the water resource management in two selected catchments in Benin and Morocco. The SDSSs of IMPETUS are implemented in a Java/XML based software framework (Enders et al., 2007).

One problem cluster of IMPETUS (which is defined as a meta-problem which requires a multi-disciplinary analysis in order to allow for drawing conclusions with respect to possible future developments (Speth et al., 2005)) addresses the evaluation of agricultural land resources in Benin (Western Africa) based on the marginality index of agricultural land use (MI). This index was originally developed by the Potsdam Institute for Climate Impact Research (PIK) and the Max Planck Institute for Meteorology (Cassel-Gintz et al., 1997; Luedeke et al., 1999), to describe and detect natural agricultural marginal sites on a global scale (spatial resolution $0.5^\circ \times 0.5^\circ$). Agricultural marginal sites are characterised by various environmental constraints limiting agricultural land use and a high risk of land degradation caused by agricultural activities. Thus, for the evaluation of the index, several natural constraints limiting agriculture under low capital input are quantified and summed to one index (see Table 1).

Remote sensing data are taken to derive some of the constraints. MODIS (Moderate Resolution Imaging Spectroradiometer) and SRTM (Shuttle Radar Topography Mission) are taken for instance to derive temperature constraints (TEMP) and high risk of erosion due to steep slopes (SL), respectively (Roehrig, 2008). Additional to the constraints, the compensation of natural aridity by irrigation near inshore waters (IC) is taken into account as it can be implemented even with low capital input. This feature was also derived by the SRTM data. As the original spatial

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Table 1
Constraints, indicators and input data chosen for the determination of MI (in dark grey: input data sets derived remote sensing, in grey: input data processed with the aid of remote sensing data).

Biophysical constraint	Indicators	Input data sets
Low natural plant production	Potential natural vegetation cover (PVEG)	Potential biomass density (PBD) (Brown and Gaston, 2005)
Temperature limitations	Temperature (TEMP)	MOD11A1-product ('Land Surface temperature'; LST)
Aridity	Length of growing period (LGP)	Rainfall data (IMPETUS)
Precipitation uncertainty	Rainfall variability (RV)	Rainfall data (IMPETUS)
Low irrigation capacity	Potential irrigation capacity (IC)	SRTM (Shuttle Radar Topography Mission) (Farr and Kobrick, 2000)
Poor soils	Soil fertility (SOIL)	Soil map of Benin by ORSTOM (Volkoff, 1976)
Risk of erosion	Slope (SL)	SRTM (Farr and Kobrick, 2000)

resolution of the MI is insufficient for applications on higher spatial scales, Roehrig and Menz (2005) and Roehrig (2008) applied the MI from the global to regional (spatial resolution of $0.05^\circ \times 0.05^\circ$) and to national scale (spatial resolution of 1 km × 1 km), respectively. Therefore, investigations have been undertaken to regionalize this approach for Benin at a spatial resolution of 1 km × 1 km using influencing factors in a higher spatial resolution and an adapted fuzzy logic based algorithm. The outcomes indicated that the index can be transferred up to the national level using input data in a higher spatial resolution and an adapted membership function (cf. Roehrig, 2008). To transfer the knowledge and results to institutions in Benin, the SDSS AGROLAND was initiated in 2005 for supporting and optimizing management strategies on the national scale. As Laudien et al. (2007) described the design of this SDSS, and Roehrig and Laudien (2009) showed the used methodological approach to generate the MI for Benin, this contribution consequently focuses on the software development and implementation of the system.

2. Area under investigation and potential user groups of AGROLAND

The country of Benin is located within the tropical West African Monsoon region at the Guinea Coast between Togo, Burkina Faso, Niger, and Nigeria (Fink et al., 2006) and covers an area of about 112,622 km^2. Benin is emblematic of an alternating outer tropical sub-humid climate. The land use in West Africa is dominated by small subsistence farms. Crops are extensively cultivated with variable fallow cycles, little use of fertilizers or irrigation (Bohlinger, 1998; Igué et al., 2004; Mulindabigwi, 2006). Thus, yields depend strongly on the biophysical conditions and water. Water for agricultural land use in tropical regions is often the most essential factor as it determines vegetation growth and thus, the agricultural calendar (Berding and van Diepen, 1982). The length of rainy seasons and the high rainfall variability are limiting agricultural activities and causing insecurity for farmers on a large-scale. Beyond favourable climatic conditions, suitable soils are essential for agriculture. Major soil types in Benin show either physical or chemical constraints for agricultural land use resulting in generally low yields (Berding and van Diepen, 1982; Igué et al., 2004).

For the country, future projections suggest that more people will have to be fed under worsening natural conditions. Adapted IPCC (Intergovernmental Panel on Climate Change), SRES (Special Report on Emissions Scenarios) climate change scenarios for the year 2025 indicate rising temperatures and declining rainfall as well as altering patterns of the growing season (IPCC, 2007; Paeth and Thamm, 2007; Roehrig, 2008). Furthermore, national studies (e.g. CENATEL, 2002 or MEHU, 2003) foresee further spatial extension and intensification of soil degradation. This outlook is especially alarming as beginning scarcity of land and water resources have already resulted in land degradation and ethnic conflicts (Bohlinger, 1998; Akapi, 2002; Doevenspeck, 2004; Mulindabigwi, 2006). According to several authors, neither a large-scale return to extensive forms of land use with long periods of fallow nor permanent cultivation under high capital input seems a realistic or sustainable opportunity to realize future needs for food (Bohlinger, 1998; Junge, 2004; Mulindabigwi, 2006). This estimation stresses the importance of an efficient and sustainable use of available potentials. Therefore, an essential first step is to obtain a better spatial knowledge of the national man–nature agrarian system including quality of land resources and population-supporting capacity, and dynamics of the system (Manshard, 1997; Eswaran et al., 1999; Shen, 2004). For setting up a land evaluation scheme for Benin, the SDSS AGROLAND focuses on the first issue, quality of land resources. As land evaluation supports rational land use planning and sustainable use of natural and human resources (Landon, 1984; Rossiter, 1996; Eswaran et al., 1999; Dorronsoro, 2002), AGROLAND is designed and developed for various national decision makers from diverse fields and institutions, such as governmental organizations, university or peace corps workers.

3. Design and development of AGROLAND

AGROLAND as well as numerous other systems of the interdisciplinary research project IMPETUS are embedded in a Java/XML based framework (Enders et al., 2007). The SDSSs within that framework are developed by using the programming environment Eclipse SDK which contains the Eclipse platform (Eclipse 3.2), tools for Java programming and the environment to develop Eclipse plug-ins. System functionalities and processors are programmed object-oriented in an abstract way. The major advantage of this abstract software development approach is the possibility to use the programmed codes multiple times in different systems. Java as an object oriented programming language allows the modelling of numerous scientific questions. It reduces the complexity of a program in terms of abstraction, encapsulation, and defined interfaces (Krueger, 2006). Object oriented programming donates an appropriate representation of the relationships between classes and objects, and increases the developer efficiency regarding the reuse of software code.

To fulfil the given requests of guaranteeing functionalities of GIS- and remote sensing within AGROLAND, the ESRI® developer library ArcGIS Engine 9.2 was used to complete the Java source code. By using ArcGIS Engine, the software developer gets the opportunity to implement spatial analysis functions as well as to provide the geo-data which is stored in a file-based geo-database (ESRI, 2007).

One of the major development requirements of AGROLAND was that the system should be a comprehensive and user-friendly SDSS. Thus, AGROLAND is designed and developed in two main modules, which are connected to each other. These two SDSS-parts are related to the two main steps determining MI (cf. Cassel-Gintz et al., 1997; Roehrig and Menz, 2005 or Roehrig, 2008): (1) fuzzification of input raster data and (2) calculation of the marginality index based on a given logical decision tree.

3.1. Fuzzification of input raster data

For all indicators and thus, input raster data, the potential use of data derived from remote sensing was investigated. Table 1 illustrates that the majority of data sets are either directly derived from remote sensing data (TEMP, IC, and SL) or from processed model outputs with the aid of remote sensing data (LGP and RV). For the other indicators, PVEG and SOIL, additional data were used. The used input data and their processing are considered in more detail in Roehrig (2008) and Roehrig and Laudien (2009). The determination of the constraints and the calculation of the marginality index is based on fuzzy logic. In using fuzzy logic within AGROLAND, the possibility of partial membership of elements to a fuzzy set is calculated by evaluating infinite truth values between 0 and 1 ($\mu \in [0;1]$) (Zimmermann, 1991; Kruse et al., 1993). This procedure is called *fuzzification*. Fuzzification means that for each value of the input data set a degree of membership of linguistic categories (low, high, etc.) is set up in relation to its contribution to a fuzzy set. In the context of the marginality index, all indicators are fuzzificated before they are summed up to MI. In doing so, a degree of naturally based constraint and marginality, respectively is assessed for each indicator defining ($0 \le \mu \le 1$) (Zimmermann, 1991; Cassel-Gintz et al., 1997). A membership index of 0 indicates that on this site agriculture is not restricted by an indicator. Such sites have a high natural potential. Membership degrees nearby 1, though, implicate that on this site great efforts are required to achieve sustainable high yields. Between these minimum and maximum values, a fuzzy set membership equation was defined for all indicators. Thus, two defined values ($x0$ and $x1$) are sufficient to set up a single membership function. Burrough (1989) or Baja et al. (2002a,b) named this point the ideal point or the standard index, b. In addition to b, they use the dispersion index, d, to set up a fuzzy membership function. Between $x0$ and $x1$, a linear membership function was defined for all indicators in the global assessment based on regional knowledge, empirical observations or measurements (Cassel-Gintz et al., 1997). Within the regionalization approach, in contrast, besides linear and sigmoidale membership functions were used in the determination algorithm. In the context of the marginality index, empirical knowledge was essential to formulate membership functions. Original membership functions were assigned as a first approximation for assessing a natural constraint. If an original membership function did not calculate a natural constraint correctly, it was modified based on the literature review and interviews with farmers in Benin (cf. Roehrig, 2008).

3.2. Calculation of the marginality index based on a given logical decision tree

In second part of AGROLAND the fuzzificated variables were combined based on a logical hierarchical decision tree. Within the decision tree all arguments for or against agricultural marginality are summed using fuzzy logic operators (see Fig. 1h; Roehrig, 2008; Roehrig and Laudien, 2009). The operator selection is ruled by the question to what extent one clause can be compensated by the other. The decision tree incorporates three fuzzy operators: fuzzy AND, OR and compansating AND.

$$\text{AND}(\wedge): \mu_{\min} \text{ from } \mu_{\text{input1}} \cap \mu_{\text{input2}}$$

$$\text{OR}(\vee): \mu_{\max} \text{ from } \mu_{\text{input1}} \cap \mu_{\text{input2}}$$

$$\text{CompAND}(\dot{\wedge}): \mu = \max\{0, \mu_{\text{input1}} + \mu_{\text{input2}} - 1\}$$

The join membership function is defined by the following equation (Roehrig and Laudien, 2009):

$$\mu\frac{\text{marg}}{\text{high}} = \mu\left(\left\{\neg\left(\frac{\text{IC}}{\text{high}}\right)\dot{\wedge}\left[\left[\left(\frac{\text{PVEG}}{\text{high}}\right)\wedge\left(\frac{\text{LGP}}{\text{high}}\right)\right]\vee\left(\frac{\text{RV}}{\text{high}}\right)\right]\vee\left[\left(\frac{\text{PVEG}}{\text{high}}\right)\wedge\left(\frac{\text{TEMP}}{\text{high}}\right)\right]\vee\left(\frac{\text{SOIL}}{\text{high}}\right)\right\}\vee\left(\frac{\text{SL}}{\text{high}}\right)\right)$$

In doing so, neither weighting factors (cf. Baja et al., 2002a,b) nor a single operator (cf. Burrough, 1989) were used.

The development of comprehensive decision support tools is associated with the need to connect the individual generated components. This matter of fact is realised by coupling the single SDSS modules using individual developed interfaces (Schneider, 2003; Shaffer et al., 2001; Hartkamp et al., 1999). These interfaces access data, embed models, and provide GIS-functionalities and RS-analyses. Hence, with AGROLAND key biophysical parameters and constraints can be visualized and evaluated interactively based on the marginality index. The MI is particularly suitable in this context as the fuzzy-logic based determination algorithm contains merely the most important biophysical constraints for agricultural land use. Thus, the system is rather tangible for decision makers. With input data in a spatial resolution of 1 km × 1 km, the system contains relevant and detailed spatial information about natural resources and key constraints on a national scale. Thus, it enables the detection of marginal and therefore, vulnerable sites, within the agrarian system.

Knowledge about key limitations is important for the planning of amelioration or compensating measures. Furthermore, scenario analyses are carried out assessing future biophysical conditions under climate change up to the year 2025. As the knowledge about future alterations of biophysical constraints and especially about vulnerable sites are essential for the development of national adaptation and precautionary strategies in time, two IPCC climate scenarios are incorporated within the determination algorithm of the index (IPCC A1B and IPCC B1).

While programming AGROLAND, a 4-phases software development approach (which is a combination between the waterfall model and the prototyping) was used to fulfil the above briefly described implementation requirements (Laudien and Bareth, 2007). By using this programming approach, additional ideas and needs of stakeholders could easily be integrated at different stages of the software development.

4. Implementation of the Spatial Decision Support System AGROLAND

The implementation of AGROLAND can be described in two different ways. The first part of this section shows the software-technical implementation containing the preliminary results of the SDSS as a software tool for decision makers. The second part presents the implementation of AGROLAND in institutions on national scale in Benin in terms of providing stakeholders the opportunity of accessing an additional software tool to support decision making processes in the working field of agricultural land usage.

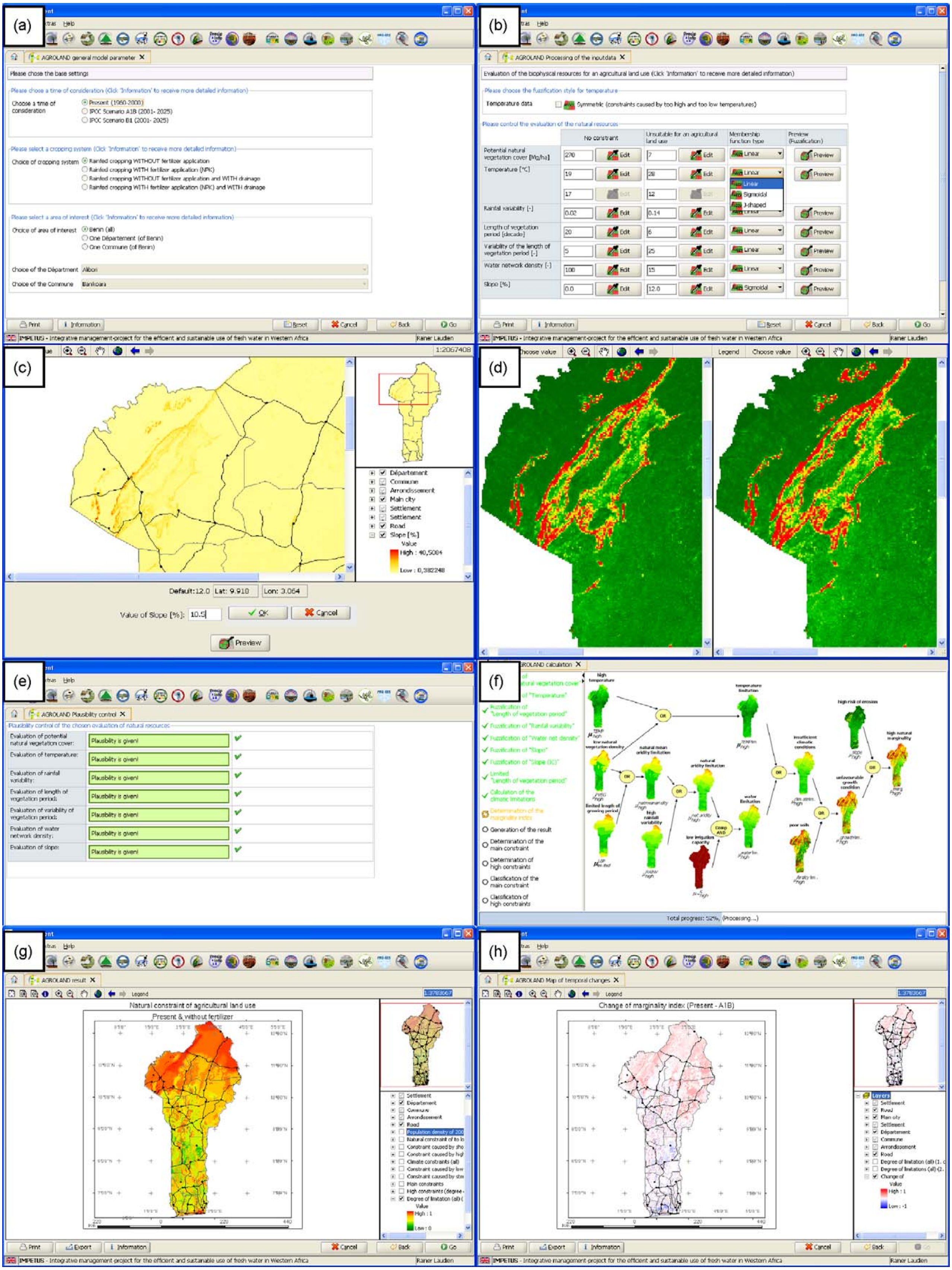

Fig. 1. Screenshots of AGROLAND (status quo: July 2009): (a) climate scenario chooser, (b) parameterization-GUI, (c) *ArcGISRasterValueChooserFormComponent*, (d) *ArcGISRasterPreviewFormComponent*, (e) Plausibility-Control-GUI, (f) Progress-GUI, (g) Map-GUI (ArcGISMapPanel showing the MI, calculated with the AGROLAND default values, present climate scenario and cropping system without fertilizer application), and (h) change-detection-GUI (present climate scenario minus IPCC A1B as an example).

4.1. Software-technical implementation

The programming of this modular designed SDSS is based on the programming language Java and therefore, guarantees a platform independent software tool. By the development of several individual interfaces based on ESRI®'s ArcGIS Engine, AGROLAND meets the requirements of being a comprehensive GIS-, RS- and model-based SDSS (Laudien, 2008). For the development of AGROLAND, detailed information about the requests, knowledge and personal needs of the potential users were considered. Hence, within AGROLAND Graphical User Interfaces (GUIs) guide the user through the SDSS and provide functionalities which were requested by the potential users. In addition to that, user interactions are enabled during run-time. These functionalities provide the user the opportunity to implement their expert knowledge and hence modify the SDSS-result interactively.

Fig. 1 shows the software-technical implementation of AGORLAND in using several screenshots. The SDSS AGROLAND starts with a screen, showing brief information concerning the system. It contains the name of the SDSS and its acronym, a short description of the content and contact information of the authors. In a first step, the user can define some general model parameters, such a time of consideration, cultivation method and the area of interest (Fig. 1a). The analyses can be undertaken on a national scale or for selected communes or arrondissements respectively. Concerning the time of consideration, the marginality index can be calculated for the present (until 2000) or future (IPCC 2001–2025). When choosing present, the index is determined taking into account biophysical conditions between 1960 and 2000. For the determination of future biophysical conditions for agricultural land use in Benin, a modified data product of PVEG and climate data products based on the two IPCC SRES (Special Report on Emission Scenarios) scenarios A1B and B1 (IPCC, 2007), assumed land use changes by the FAO, and adapted membership functions are incorporated (Roehrig, 2008). By selecting a future scenario, the effects of climate change on the biophysical resources of Benin are investigated. A1B denotes a future with very fast economic growth and a rapid introduction of innovative and efficient technologies. Additionally, global population is expected to peak in mid-century and decrease thereafter. The IPCC SRES scenario B1 contains equal presuppositions concerning global population development as A1B. The differences are based on economic and environmental developments.

In addition, the user can choose between the following different cropping systems:

- Rain fed cropping WITHOUT fertilizer application
- Rain fed cropping WITH fertilizer application (NPK)
- Rain fed cropping WITHOUT fertilizer application and WITH drainage
- Rain fed cropping WITH fertilizer application (NPK) and WITH drainage.

The option "Rain fed cropping WITHOUT fertilizer application" is the traditional system in the major part of Benin. If this option is selected, the given soil properties, derived directly from the soil maps, are used for the determination of the MI. If the user selects systems with fertilizer application, given chemical soil constraints assigned to the soil type are assumed to be totally compensated. If the user selects systems with drainage, given physical constraints caused by soil hydrology are presumed to be totally compensated. In doing so, soil conditions improve and consequently, the overall natural conditions for agricultural land use get also better.

Based on the described options above (climate and cropping system), AGROLAND accesses its ArcGIS-file geo-database, loads the influencing factors (potential vegetation cover, temperature, rainfall variability, length and variability of vegetation period, potential irrigation capacity, soil fertility and slope), and provides these raster inputs for the first system module (cf. chapter 3) in terms of ArcGIS raster files.

Within the Parameterization-GUI (Fig. 1b), functionalities are implemented, which enables the user to modify the evaluation of the natural constraints editing the fuzzification membership function. In addition, the user can choose the shape (linear, j-shaped or sigmoidal) of the function between $x0$ and $x1$. This function is calculated by AGROLAND processors and visualized for every single input raster layer based on a GIS map visualization (Fig. 1c). Furthermore, an additional functionality, the Preview-functiony (see button on Fig. 1c), visualizes the effects of these modifications after selecting a pixel value from the map. Another window opens illustrating the outcome of the fuzzification based on the default and the modified thresholds within two parallel GIS maps (Fig. 1d). Red colors (For interpretation of the references to colour in the text, the reader is referred to the web version of the article.) (values around 1) illustrate regions with severe restrictions caused by the natural constraint, which is considered at this moment. Furthermore, yellow colors (values around 0.5) show middle and green colors (values of 0 or slightly higher) low or no constraints. Both images are linked so that the results can be easily compared qualitatively and quantitatively by using the implemented GIS-tools.

The Parameterization-GUI is followed by a Plausibiliy-Control-GUI which checks if the given/modified values $x0$ and $x1$ of the input raster data are reasonable (Fig. 1e). If so, the second module of AGROLAND can be accessed. This SDSS core module generates the fuzzification outputs based on the input rasters and calculates the MI with regard to the predefiend logical decision tree (Fig. 1f). During the determination process the user can follow the stage of the assessment visually by the built up of that tree in a Progress-GUI. Additionally, the coloring of the list illustrates the processing status. Finally, the Map-GUI which contains numerous GIS-tools and functionalities, shows the result, the MI as a raster layer in a spatial resolution of 1 km × 1 km (Fig. 1g). Additionally, all constraints can be demonstrated by checking the specific layers in the layer list.

After the marginality index has been successfully determined, the user has the opportunity to calculate changes between the current and future biophysical conditions as well as between different cropping systems. In doing so, the user can analyse the impact of climate change as well as the impact of cropping systems improving the soil fertility. This resulting raster is drawn in the Change-Detection-GUI. Fig. 1h shows the change based on the substraction of the present climate scenario minus IPCC A1B as an example. This analytical result indicate that climate change will affect the biophysical conditions in Benin notably. Until 2025, both climate and general biophysical conditions for Benin will worsen according to the IPCC scenarios A1B and B1. Differences between the two scenarios are very small, which verify the general trends of the analyses. Climate change affects all parts of Benin with strongest aggravations in the south and north, where the degree of marginality will ascend at about 0.5. Additionally, several areas in the western centre are affected by high changes. Concerning the climate limitations particularly temperature will become a severer constraint, but also the length of growing season will slightly decrease and its variability increase. Thus, the beginning and ending of the rainy season will be more variable.

4.2. Transfer to institutions in Benin

The implementation of AGROLAND, in terms of transferring the system to stakeholders on the national scale of Benin, was accomplished by a two-step approach.

In a first step, various meetings with single stakeholders of different working fields were arranged investigating potential user groups and specific application fields in Benin. Mainly national decision makers and advisers working about environmental research and conservation, sustainable agrarian development, food security or aid to developing countries (e.g. governmental organizations, university, civil society organisations or peace corps workers), were involved. The meetings with the stakeholders were already carried out during the initial software development process of AGROLAND to discuss the system conception, functionalities, usage, and results. To guarantee a sustainable usage of the system in a decentralized country like Benin, where the administration needs tools and methods to inform the public in an adequate way, the early integration of potential users in the development process was particularly important for a successful implementation in different working fields. Errors and unnecessary features were detected in a preliminary stage, additional needs addressed, the terminology adapted and the outcomes of the meetings implemented in later versions of AGROLAND. Examples are the set up of (i) the *ArcGISRasterValueChooserFormComponent* (Fig. 1c) with various opportunities for better orientation or (ii) the *ArcGISRasterPreviewFormComponent* (Fig. 1d). For a better orientation, geographic information (latitude and longitude) and the scale (upper right corner) are given, when raster data are visualised. In addition, administrative boundaries, cities as well as streets can be overlaid. Furthermore, common GIS-functionalities were implemented. While zooming into the image, the region of interest is highlighted within a red box in the overview image on the right side. In addition, the opportunity to select different scenarios and areas of interest were implemented to enhance impact analyses for the users.

In addition to the design and development meetings in Benin, workshops were carried out in a second step, with 5–20 participants to test beta versions of AGROLAND. In 2008, for instance a one-day workshop was organised with around 20 participators of different organizations to test the beta version of AGROLAND which already included all input data and major functionalities, such as climate scenario analyses. During that day the content and methods of the system as well as the fields of application were presented and discussed. On this occasion additional concerns were addressed with regard to the application in terms of fertilization, irrigation, increasing yields, and improving productivity. The illustration and explanation of the background of AGROLAND, particularly within the scientific and stakeholder communities, was found to be essential for a successful and effective use of a SDSS in terms of interpreting its outcome. One year later in 2009, the revised version of the system was presented to the main stakeholders and installed on several computers. Very recently, a questionnaire has been send to the participants to receive information how their experience with the system has been. Although, not everybody has already answered and thus, no final remarks can be given, the received feedbacks are promising. Thus, in July 2009 Mr. Ulrich from the *Délégation à l'Aménagement du Territoire* wrote in an email: *"Je vous remercie pour la présentation des instruments d'impétus que vous nous avez fait connaître. Comme le Délégué à l'aménagement du territoire l'a dit cela présente un fort intérêt pour nous et on devra plus tard développer des outils similaires selon nos objectifs."*

The specific training activities for AGROLAND were weaved into a series of courses dealing with basics necessary for the successful application of several SDSSs developed within the IMPETUS project: In three one-week seminars about GIS, RS and environmental modelling were organised for a selected group of participants of different institutions, which included students and primarily stakeholders of different SDSSs. In addition to the training of essential methodological basics, the courses aimed to present the developed SDSS to a broader community in Benin to raise the interest in the systems.

5. Conclusion

The marginality index of agricultural land use (MI) was successfully determined for Benin on a national scale in a spatial resolution of 1 km $\times$ 1 km (Roehrig, 2008). MI detects marginal areas based on key biophysical constraints. The values of MI ranges from 0 to nearly 1, which indicates that Benin contains sites with very good biophysical conditions for agricultural land use (MI-values about 0), but also contains regions, where high natural constraints make them prone to land degradation while they are under cultivation (MI-values about 1). These areas may be more valuable for pasturage or forestry. In general, the approach determines generally moderate conditions for agricultural land use. The outcomes demonstrated that primarily low soil fertility restrict the suitability of agricultural land use on the majority of sites in Benin. In addition, limited length of the growing period and high rainfall variability are the crucial biophysical constraints on the national scale, which should be compensated to receive higher yields. Climate change will affect the biophysical conditions in Benin notably. Until 2025, both climate and general biophysical conditions for Benin will worsen according to the IPCC scenarios A1B and B1. Concerning the climate limitations particularly temperature will become a severe constraint, but also the length of growing season will also slightly decrease and its variability rise.

The index is the main component of the SDSS AGROLAND. Thus, the system can be used by decision makers in Benin to evaluate current and future agricultural land resources. Stakeholders in Benin did show a significant interest on AGROLAND, particularly with regard to the changes in natural landscapes within the scope of global change (Laudien et al., 2007). The conducted presentations and talks with the potential users approved that the chosen limitations within the system represent the topic sufficiently. As the tangibility of the system is high, the limited number was named as a big advantage to the most crucial ones. In addition to that, the training and education meetings illustrated application fields (e.g. science, national administration, or public body), in which SDSSs can be used to support management strategies. In general, these sessions demonstrated that SDSSs provide additional helpful tools for decision making processes.

The programming of the dynamic interactive SDSS AGROLAND, which was done by using Java and ArcGIS Engine, illustrates a high flexibility with regard to the implementation of GIS-, model- and remote sensing analyses. AGROLAND was programmed in a comprehensive and user-friendly way to meet the requirements of providing different users in Benin the opportunity to evaluate agricultural land resources. Required SDSS-functionalities were embedded by developing and implementing specific Graphical User Interfaces and possibilities to interact with the system during run-time.

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