

Integrated Soil and Water Management in high-yielding agricultural landscapes in Brazil - scenario and model based land use concepts for the sub-humid tropics (ISWaMa-Bras)

Partner Country: Brazil

Thematic Issue: Water Management and Land Management

Keywords: Land use/cover change, irrigation, Climate Change, groundwater recharge, surface water quality, water resources management, river basin management, regional planning

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Duration of project: 36 months, 1.1.2013 - 31.12.2015

German Partners:

Helmholtz Center for Environmental Research UFZ
University of Applied Science Weihenstephan-Triesdorf
Technische Universität Dresden
Prof. Dr. F. Makeschin Consult
Sachsen Wasser GmbH

Brazilian Partners:

SECTES - Secretaria de Estado de Ciência, Tecnologia e Ensino Superior
UNESCO-HidroEX - Fundação Centro Internacional de Educação, Capacitação e Pesquisa Aplicada em Águas
EMBRAPA__Empresa Brasileira de Pesquisa Agropecuária, Cerrados
UFV - Universidade Federal de Viçosa
UNIFEI - Universidade Federal de Itajubá, Campus Itabira
CPRM - Companhia de Pesquisa de Recursos Minerais
UFMG - Universidade Federal de Minas Gerais
UFRJ - Universidade Federal de Rio de Janeiro
COPASA - Companhia de Saneamento de Minas Gerais

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1. Background

The region Triângulo Mineiro in the state of Minas Gerais is part of the Cerrado biome which came recently under substantial pressure due to strong land use/cover change (LUCC). Major driving force of LUCC in the region is the expansion of cropland for energy plants, *i.e.* mostly sugar cane and soy bean. The effects on water resources are already severe. During dry periods a substantial decrease of base flow and reduced groundwater recharge has been observed. In addition, a substantial decline of water quality is taking place, since the application of fertilizers and pesticides increased with the expansion and intensification of agriculture. Another interference with regional water resources is caused by increasing demand for irrigation water. This aggravates the water conflict, especially during times of general water scarcity, *i.e.* dry period. In addition, global climate models predict for western Central Brazil longer dry periods and less annual precipitation, which makes stronger dry spells more likely for the future.

The study is for three reasons of interest for the region,

- i. The region is part of the Guarani aquifer recharge area. This aquifer is one of the largest global aquifers and a potential source for the water supply of 25-35 million people.
- ii. The region hosts several catchments of large reservoirs, producing 67% of the state's power production along the Rio Grande river
- iii. The pollution of water resources and reduced water availability during dry periods is a potential threat for human health and economic development of the region
Brazilian and German partners see an urgent need for a concept of integrated water and land management to achieve a sustainable use of land and water resources. However, the need of integrated concepts for land and water management is not limited to Brazil or Latin-America, results from our study might be transferred to other emerging countries.

2. Targets

The overall objective of the proposal is the development of a (example) concept for integrated management of water and land resources for a study area in the sub-humid tropics of Brazil (Rio Grande, Triângulo Mineiro). The core of the project is the analysis of the land-water system and the optimization of land use and water use, by taking LUCC and climate change into account. In detail there are seven major objectives.

1. Monitoring of LUCC by using remote sensing and development of land use scenarios
2. Analysis of regional climate and prediction of regional climate change
3. Modeling of groundwater (flow and quality)
4. Surface and ground water management (river basins, limnology)
5. Assessment of land use effects on water resources
6. Development of a tool for river basin management and regional planning
7. Capacity development as base for sustainable water management

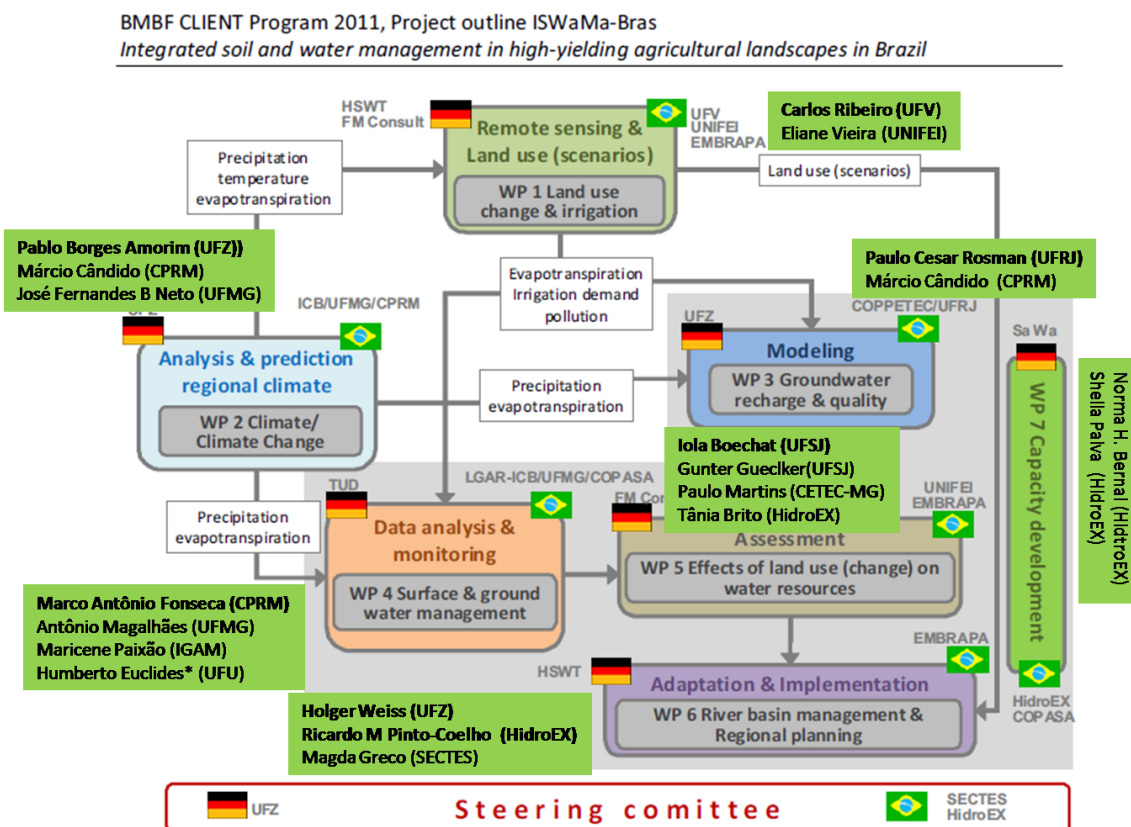


Figure 1: Project structure

German Partners

HSWT = University of Applied Science Weihenstephan-Triesdorf, Dept. Forestry

UFZ = Helmholtz Center of Environmental Research, Dept. Groundwater remediation

TUD = Technische Universität Dresden, Institute of Groundwater Management

FM Consult = Prof Dr. F. Makeschin Consult

Sa Wa = Sachsen Wasser GmbH

Brazilian Partners

UFV = Universidade Federal de Viçosa

UNIFEI = Universidade Federal de Itajubá, Itabira

EMBRAPA = Empresa Brasileira de Pesquisa Agropecuária, Cerrados

ICB/UFMG = Instituto de Ciências Biológicas, Universidade Federal de Minas Gerais

CPRM = Companhia de Pesquisa de Recursos Minerais

LGAR-ICB/UFMG = Instituto de Ciências Biológicas, Departamento de Biologia Geral / Universidade Federal de Minas Gerais

COPPETC/UFRJ = Fundação Coordenação de Projetos, Pesquisas e Estudos Tecnológicos / Universidade Federal de Rio de Janeiro

SECTES = Secretaria de Estado de Ciência, Tecnologia e Ensino Superior

HidroEX = UNESCO HidroEX

COPASA = Companhia de Saneamento de Minas Gerais

3. Proposed solution

The proposal is based on a systematic approach identifying the important compartments and processes of the land-water-system. Figure 1 shows work packages as well as responsible groups. The structure of the proposal represents the concept for an integrated water and land management. The principal idea of the European Water Framework Directive, *i.e.* integrated river basin management, is also the core of the approach. It considers natural, economic and social frame conditions in a river basin as complex system. The work packages listed in section 3 are closely interlinked. Choice of example areas, land use scenarios and analysis of existing data will be in close collaboration with the Brazilian partners.

4.0 Sub-projects (WP)

WP 1 Remote Sensing and Land use (scenarios) (HSWT, FM Consult, UFV, UNIFEI, EMBRAPA)

Land use/cover change (LUCC) in the region, as in Brazil in general, is a very dynamic process and leads to substantial losses of natural vegetation due to expansion of croplands and urban areas. Remote sensing is a powerful tool for detecting and quantifying and use/cover changes (LUCC). Especially multi-temporal analysis and modern approaches like MODIS (Moderate Resolution Imaging Spectroradiometer) are suitable to detect historic extent and details of LUCC. Analysis of historic LUCC and prediction of future LUCC is a precondition for an integrated land and water management in frame of river basin management as well as model-based simulation of LUCC and climate change effects on water resources. In detail the work package encompasses following steps,

- a. Creating historic land use maps to detect and to quantify LUCC during the last decades
- b. Land use maps with high temporal resolution and information on crop rotation (MODIS)
- c. Development of land use scenarios under frame conditions of climate change and changing economic conditions
- d. Development of geographic explicit land use scenarios along realistic, pessimistic and optimistic story lines.

WP 2 Analysis and prediction of regional climate change (UFZ, ICB / UFMG, CPRM)

The objective of WP 2 is to formulate scenarios of climate behavior for Triângulo Mineiro for a 50 years period. Global climate models predict for western Central Brazil longer dry periods and less annual precipitation, which makes stronger dry spells more likely for the future. However, effects of regional global climate change on water resources are not very well studied and understood. For understanding past, present and future regional climate systems the collection and testing of data in a data base is a necessary precondition. Needed data are long-term time series (30 years) for precipitation, temperature and other relevant variables, e.g. humidity. This data will be the base for statistic downscaling approaches Results will be compared to verify the consistency of the models with observations and will guide possible parametrical adjustments of the models to the Triângulo Mineiro region. Finally, the results will be used to construct plausible scenarios for the future distribution of rainfall and temperature. In detail WP 2 consists of the following steps,

- a. Collection and assimilation of all relevant climate data available in a climate databank with consistency and homogeneity tests
- b. Analyse trends, as well as it significance, of observed data
- c. Assess global climate change models and scenarios
- d. Develop regional climate scenarios based on statistical and dynamic downscaling

WP 3 Groundwater modeling (UFZ, COPPETEC / UFRJ)

The WP 3 focuses the development of appropriate and efficient groundwater management strategies for the region Triângulo Mineiro based on a representative conceptual groundwater flow and solute transport model. With respect to this, the conceptual model of the study area is involving all relevant environmental compartments (hydro-geological system, hydrologic features and hydro-geochemistry) and addresses finally the key issues of groundwater quantity and quality. A representative model abstraction of prevailing site characteristics and related predictive model scenarios serves for the validation and assessment of sustainable groundwater management strategies. Therefore, the predictive scenarios are designed iteratively by considering proposed groundwater management options under varying model inputs such as e.g. climatic features, land-use scenarios, and groundwater extraction. In principle, setting up the groundwater model involves the following specific working steps,

- a. The creation of a 3-D structural model which is defining the hydraulic system spatially concerning its hydro-geological dimension and sub-units. Therefore, geological data from boreholes/profiles and (hydro-) geological maps are required
- b. Model parameterization regarding hydraulic and hydrologic characteristics. This includes the assignment of the hydraulic conductivity, porosity, groundwater recharge (precipitation & evapotranspiration), surface waters, spring discharges, groundwater levels, groundwater quality, groundwater extraction, usage of pesticides/fertilizers, and irrigation rates.
- c. A successful model calibration of available time-variant/invariant parameters constitutes the model for being proven to analyse predictive model scenarios of the study site under varying input quantities.

Available input data needs to be examined and processed; probably non-available data need to be collected. Relevant processes and interactions of system components are identified at the basis of model sensitivity analyses. Based on proposed model scenarios related impacts on the groundwater quantity and quality are estimated by numerical modelling. Finally, in regards to this, sustainable groundwater and land-use management recommendations are derived for the study site from the most effective utilization concepts.

WP 4 Surface and groundwater management (TUD, LGRA-ICB / UFMG, COPASA)

The major objective of this work package is to assess current water management practice and to develop improved (“optimized”) strategies taking into account information about available water resources, water quality, land use, and stakeholder interests. This will be achieved by defining and evaluating various future management scenarios differing in, for instance, water extraction (amount, locations), regulation of surface water by dams, irrigation practice, and climate change predictions.

The set-up of realistic future scenarios requires a thorough understanding of the entire hydrologic system of the Triângulo Mineiro. This, in turn, must be based on the analysis of hydrological, limnological and climate data. Available data as well as climate change predictions are expected to be subject to uncertainty which needs to be quantified via appropriate statistical or geostatistical techniques. Uncertainty is transferred to proposed management options which will therefore not only consist of definite (or deterministic) recommendations. Rather, water management recommendations will also be associated with bandwidths (e.g. confidence intervals) obtained by stochastic system analysis involving, for instance, Monte Carlo or fuzzy logic approaches. This step will strongly rely on the groundwater model developed in WP 3 and on a series of complementary surface flow simulations to be carried out within WP 4. Compatibility of

surface and subsurface models will have to be addressed in order to adequately represent transfer mechanisms (water, nutrients, pollutants) between both compartments.

WP 5 Assessment of land use/cover change (FM Consult, UNIFEI, EMBRAPA)

LUCC is well known to have severe effects on water resources. We expect changes of vegetation cover, *i.e.* from natural vegetation to seasonal crops, to have substantial effects on evapotranspiration, groundwater discharge and water quality. In addition, increasing demand for irrigation water for croplands is a further stressor and will cause conflicts with other demands for water, *e.g.* drinking water or hydro power. The work package focuses on assessing effects of land use practice in terms of crop rotation, soil management practice, fertilizing and plant protection. Especially the geographic distribution of LUCC will be in the focus of the WP. WP 5 will be in very close relation to WP 1 and 6. In detail the WP consist of the following major steps,

- a. Assessment of common, predicted and recommended land use practices
- b. Site specific assessment with classification of hot spot areas and areas of high ecological elasticity

WP 6 River basin management and regional planning (HSWT, EMBRAPA)

The integration of river basin management and regional planning is based on an overall view of the land-water system and is the framework for the product of the project, *i.e.* integrated concepts for land and water management. The principal idea is to develop concepts of land/water management on the base of physical properties of the catchment, *e.g.* soils, aquifers, relief, climate etc. and anthropogenic factors, *e.g.* agriculture, water use etc. A spatially explicit recommendation in terms of optimized land use scenarios is the overall aim of the WP. WP 6 will pick up results from WP 1-5 and integrate results in a concept of land and water management. For optimal effects on participation web-based planning tools will be used, *e.g.* "Letsmap do Brasil" or "Stoffbilanz", which enables users to assess effects of LUCC scenarios on water resources. In detail, the following major steps are planned

- a. Modification of a web-based planning tool
- b. Identification hot spot areas and zones of for intense agriculture

WP 7 Capacity development (SaWa, HidroEX, COPASA)

Capacity development, *i.e.* training of (young) scientists and non-academic staff, is the precondition for a successful long-term implementation of concepts for integrated management of water and land resources. The cooperation with the UNESCO HidroEX International Center for Education, Capacity Building and Applied Research will guarantee the optimal involvement of local practitioners and experts. There will be several short courses (1-2 weeks) and executive workshops (1-2 days) be offered. Possible thematic issues will be,

- a. Theoretical and applied basis of conservation of water resources (zoning, laws, standards, rules)
- b. Waste water fees, polluter pays principal
- c. Water quality management (monitoring, laboratory etc.)
- d. Sustainable agriculture as mechanism for preventing water pollution
- e. Concept of water protection zones

5.0 National and international cooperation partners

Organization Core competences Staff Tasks in project

Germany

Helmholtz Center for
Environ. Research UFZ
*Modeling of ground
water flow and transport*
1000 WP 2

WP 3

Steering committee

Univ. of Applied Sci.
Weihenstephan

*Land use, water and
land management,
regional planning*

300 WP 1

WP 6

Technische Universität
Dresden

*Surface and ground
water management,
numerical modeling*

1000 WP 4

Prof. Dr. F. Makeschin

Consult

*Environmental
consulting, capacity
development*

<10 WP 5

Sachsen Wasser GmbH *Capacity development
and consulting in water
resource management*

<100 WP 7

Brazil

SECTES - Secretaria de Estado de Ciência, Tecnologia e Ensino
Superior Steering committee
UNESCO HidroEX City of Waters WP 7 – LGAR UFMG

Steering committee

Universidade Federal de Viçosa WP 1
Universidade Federal de Itajubá, Itabira WP 1 WP 5
EMBRAPA, Cerrados WP 1 WP 5 WP 6
Universidade Federal de Minas Gerais WP 2 WP 4
Companhia de Pesquisa de Recursos Minerais WP 2
Universidade Federal de Rio de Janeiro WP 3
COPASA - Companhia de Saneamento de Minas Gerais WP 4 WP 7

6.0 Sustainability potential

The project aims at creating the base for a sustainable management of land and water in the study region. The core of the project is the optimization and trade-off between land management in terms of agricultural exploitation and water management, *i.e.* multiple use of water or guaranteeing water quantity and quality. In detail, the following aspects will provide a high sustainability potential.

Maintaining water supply for communities and agriculture o Groundwater management monitoring of quality/quantity, conservation measures and controlled extraction, River basin management, monitoring of quality/quantity and conservation measures. Concepts for intense agriculture as major part for regional economy, adapted land use with best practice, zoning of river basins (delineation of suitable high intensity areas, exclusion of hot spot areas), capacity development, technologies and integrated concepts.

7.0 . Estimated costs

Total costs for the project will be ca. 2.7 million €. Nearly 50% will be financed by SECTES - Secretaria de Estado de Ciência, Tecnologia e Ensino Superior with 2.500.000 Brazilian Reais (approx. 1 million €) for the Brazilian partners. Requested funding from BMBF for the German partners is summarized in the following table:

Estimated costs (in Euro)

Organization Cost Quota Requested funding

Helmholtz Centre for Environmental Research UFZ

Personnel 72 man-months 395.000 100 % 495.000

Travel, material, expenses 118.000 100 % 118.000

sub total 613.000

Technische Universität Dresden

Personnel 36 man-months 200.000 100 % 200.000

Travel, material, expenses 70.000 100 % 70.000

sub total 250.000

University of Applied Science Weihenstephan-Triesdorf

Personnel 36 man-months 200.000 100 % 200.000

Travel, material, expenses 70.000 100 % 70.000

sub total 250.000

Prof. Dr. F. Makeschin Consult

Personnel 15 man-months 90.000 60 % 54.000

Travel, material, expenses 50.000 60 % 30.000

sub total 84.000

Sachsen Wasser GmbH

Personnel 36 man-months 200.000 60 % 120.000

Travel, material, expenses 100.000 60 % 60.000

sub total 180.000

Total requested funds 1.377.000

8.0 Commercialization of results

The demand for integrated concepts for land use management and groundwater management in Brazil is urgent, since pressure on land and water resources is due to dynamic economic development increasingly high. We see a vast market for concepts of integrated land and water management (in Latin America), especially for areas that have been not in the focus of research activities, *i.e.* Cerrado biome. The target groups for our product – land use concept - are institutions operating on regional scale, *i.e.* state, federal or national authorities, regional water supply companies, large agro-enterprises. The transfer to other regions in Brazil or Latin America is possible and intended.

9.0 Measure for the protection of intellectual property / IPR

During the entire project, starting from the writing of the detailed project proposal, confidentiality agreements with all involved partners will be upheld. During the preparation of the detailed project proposal, an IPR protection plan will be developed.

10.0 Additional information about the partner country

Needs in the partner country Very dynamic change in land use/cover (LUCC) is a common process in emerging countries.

There are two major processes to name in Brazil, urbanization and expansion of agricultural areas on cost of natural areas. Recently the Cerrado biome, the second largest biome in Brazil after the Amazon rain forest, came into focus of these processes. This resulted also in severe effects on other media such as soil and water, *i.e.* soil degradation, pollution of surface and ground water and overuse of water resources. Both soil and water are limited resources and are subject to a variety of, mostly conflicting, interests. For the study region, optimized concepts for land and water management/use are desperately needed to guarantee a sustainable use of natural resources as well as to maintain socio-economic balance in the region.

Expected results in the partner country The partners in Brazil expect an approach which provides a base to guarantee the sustainable use of natural resources in the region. This includes technological solutions to remediate degraded resources as well as advanced concepts to manage land and water resources or to predict development of natural resources. A major effect of all activities is the involvement of young scientists and managers for rise awareness for solutions and to train them (capacity development). *Existing contacts and previous collaborations with the partner country* The German partners and some of the Brazilian partners participate in the project IWAS, with a focus on Brazil. Within this project several other contacts and agreements have been made. Within this context the following agreements have been signed,

- _ Agreement with EMBRAPA, Cerrados, signed 21.8.2010
- _ Agreement with ANA, signed 24.5.2010
- _ Agreement with CAESB, signed 28.7.2009
- _ Agreement with SECTES/MG and HidroEx, signed 8.6.2011

Information about the participation of relevant stakeholders

The participation of relevant stakeholders is guaranteed by the principal involvement of HidroEX. The institution unites all important stakeholders in the field of land and water management on the international level, *e.g.* UNESCO-IHE, national level, *e.g.* Agência Nacional de Águas, EMBRAPA, and on the regional level, *e.g.* EMATER-MG, Governo de Minas.

Market analysis and competitive analysis of the proposed research topic in the partner country

There are numerous globally acting consulting companies with water resource management related portfolios. However, especially in Brazil, the experience from governmental, research institutions as well as from end-users is that studies executed by these companies have rather synoptic-descriptive character and lack a scientifically sound base. To our knowledge, there is no such a scenario- and model-based regional study planned or executed. For details on demand-side market analysis see Section 7. *Review and evaluation of programs* Besides of the CLIENT program some EU programs might be suitable for future submission of proposals in the field of this proposal. These are especially the programs of FP 7, *e.g.* calls in Environment, 6.2 Sustainable use and management of land and seas.

Declaration of intent of all partners

See appendix