Integrated Water Resource Management in Brazil

Edited by Carsten Lorz, Franz Makeschin and Holger Weiss

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Chapter 1

Introduction

C. Lorz, F. Frimmel, W. Günthert, S. Koide, F. Makeschin, K. Neder, W. Uhl, D. Walde, H. Weiss and E. Worch

1.1 INTEGRATED WATER RESOURCE MANAGEMENT IN CENTRAL BRAZIL

The demand for concepts of integrated water resource management (IWRM) is increasing worldwide due to rising awareness for sustainable use of water resources and due to pressure from society for reliable and healthy water supply. For many regions in South America, where water scarcity and/or water quality are issues, this applies in particular. In addition to the specific natural conditions, that is, strong seasonal contrasts and strong climatic variability, the rapid changes of land use/cover – mostly caused by the drastic expansion of agricultural land and urbanization processes – have severe effects on water resources. Effects of land use change on water resources seem to exceed the effects of climate change, but global climate models predict substantial changes in future climate and in consequence, severe effects on water resources are to be expected. As a result of the rapid changes of land use, rising demand for water supply and rising production of waste water can be expected – both in terms of amount and spatial expansion – due to higher population densities caused by natural population growth and migration as well as higher per capita consumption. The understanding of the complex interactions between water, climate, land use, society and water technologies is a crucial step to achieve sustainable water supply with high standards in regard of quality and reliability.

Central Brazil belongs to the type of region described above. As climate change and very dynamic processes of urbanization and expansion of agriculture are happening in this area, substantial impacts on water resources have been observed. Urbanization and high shares of urban population as well as substantial expansion of croplands are seen as major causes for ecological problems in Brazil, for example, not sustainable use and pollution of water resources (Braga *et al.* 2008; Hespanhol, 2008; Tucci, 2001, 2008). The adaptation to changing frame conditions as well as the prevention and mitigation of negative impacts on water resources are the main challenge for the sustainable water supply of the region. Therefore, a consortium of Brazilian and German partners decided to start the IWRM project IWAS-ÁGUA DF[1] focussing on the Distrito Federal including the national capital Brasília.

1.2 THE PROJECT IWAS-ÁGUA DF

During the period 2008–2013 the project IWAS-ÁGUA DF was carried out as joint activity by Brazilian and German partners, aiming at providing the scientific base for the sustainable use of water resources within the Distrito Federal (DF). The study area was chosen because of its model character due to outstanding data base on water relevant information and the existing high standards in terms of technology and capacity development in the water sector.

The general objective of the project was to contribute to the development of an IWRM approach for the Distrito Federal, identifying causes of problems and proposing solutions to maintain water supply for the region also with a focus on

[1]IWAS-ÁQUA DF was funded through the program 'International Water Research Alliance Saxony (IWAS) – Management of Water Resources in Hydrological Sensitive World Regions' by the BMBF (FKZ 02WM1165/66 and 02WM1070) and by Brazilian Partners. For more information go to http://www.ufz.de/iwas-sachsen/index.php?en=18049

changing frame conditions. The project follows the DPSIR approach (EEA, 1999 [Figure 1.1]), which identifies the driving forces and pressures on the compartments river basins, drinking water and waste water systems and analyses the state, impacts and response of these compartments. In effect, this results in a subdivision into three major complexes – which represents at the same time the structure of the book – (a) river basins and water bodies (Chapter 2–5), (b) surface/drinking/waste water (Chapter 6–8) and (c) capacity development (Chapter 9).

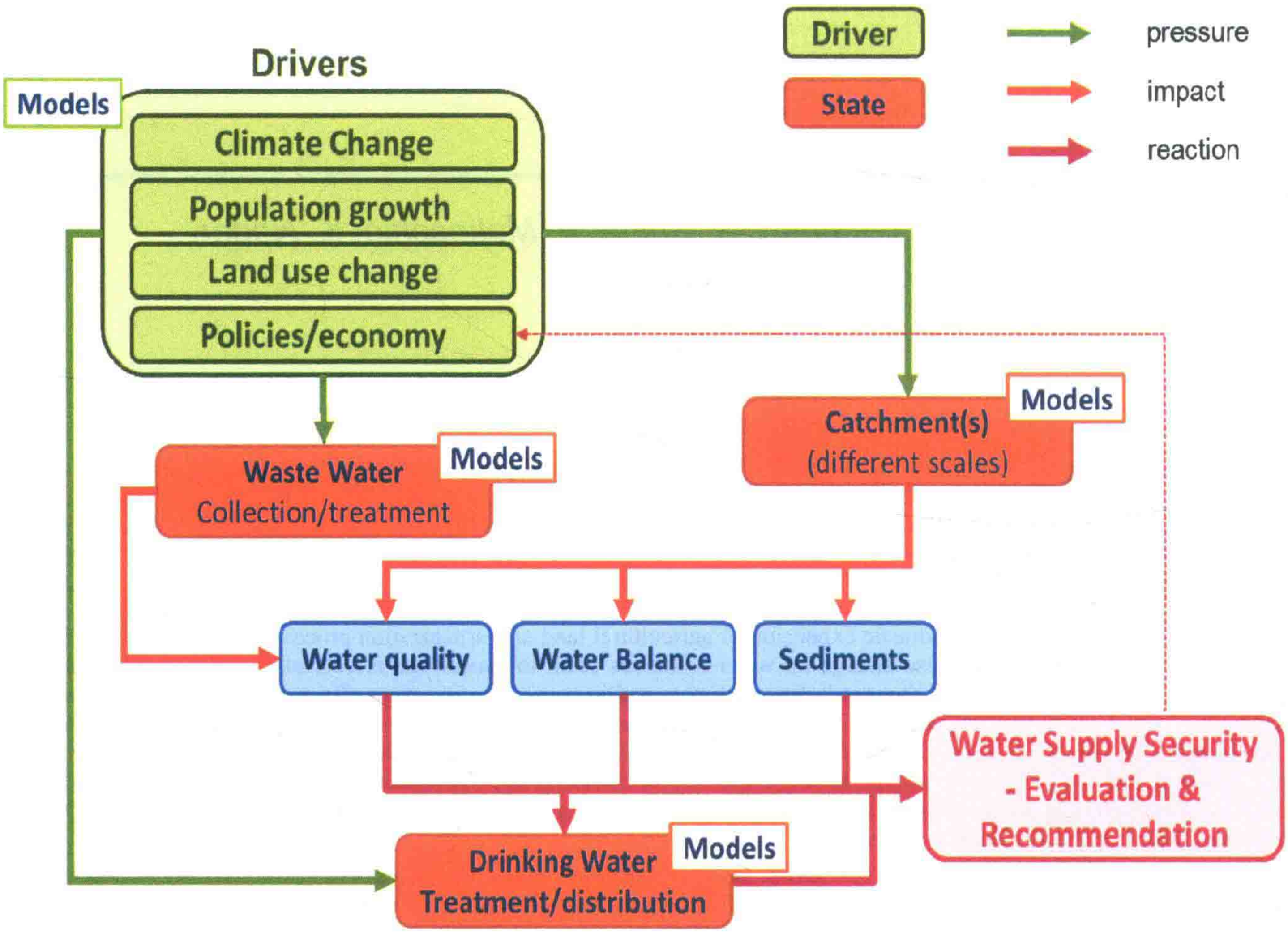

Figure 1.1 Driving forces-Pressures-State-Impacts-Responses (DPSIR) scheme of the project (modified after Lorz *et al.* 2012).

1.3 THE STUDY REGION

1.3.1 Climate

The Distrito Federal covers an area of 5790 km^2 and is located in the high plains (*planalto*) of Western Central Brazil with altitudes between 1000 and 1450 m a.s.l. The topography might be characterized as rolling landscape where steep slopes are rather an exception. The geological underground consists of series of metasediments, that is, argillic to sandy rocks of the Palaeozoic period. Soils are mostly Oxisols, Cambisols and Gleisols developed in the regolith mantles of the rocks mentioned above.

The study region belongs to the outer Tropics (Aw climate after Köppen) having mean annual precipitation of 1300–1700 mm and mean annual temperatures of 20–21°C (WMO, 2010). The climatic conditions are characterized by strong seasonality. The dry season comprises 5–6 months, during south-winter, from late March to late September. The average amount of precipitation during rainy season is four times higher than during dry season. However, the temporal variability of mean annual temperature and precipitation as well as in terms of seasonality is high.

Effects of climate change are already observable for the last three decades (Borges *et al.* 2013). Since the end of the 1970s a trend to longer dry periods with less rain days at the begin and the end of the dry seasons as well as a general trend for lower mean annual precipitation have been observed for five stations in the Distrito Federal (Table 1.1). However, this trend is not significant for all stations and will not explain fully the dramatic decrease of base flow discharge during the dry period (Lorz *et al.* 2012). For the future, a further increase of seasonality, that is, loner dry seasons, is predicted (Borges *et al.* 2013)

Table 1.1 Mean annual precipitation for five stations (see Figure1.2 for location) in the Distrito Federal and trends (Kendall´s tau) for rain days and annual precipitation (Mann-Kendall test) (Lorz *et al.* 2012).

Monitoring station	Period	MAP (mm)	Rain days April/May	Rain days October	Annual precipitation
A 1547013	1978–2009	1332	*–0.25⁺ (May)*	**–0.26***	*–0.24⁺*
B 1547014	1979–2006	1480	**–0.36** (April)**	*–0.18⁺*	*0.08⁺*
C 1547015	1978–2004	1419	*–0.17⁺ (May)*	**–0.26***	*–0.04⁺*
D 1548007	1978–2008	1560	*–0.25⁺ (May)*	**–0.26***	*–0.12⁺*
E 1548008	1979–2006	1444	**–0.31* (May)**	**–0.35****	**–0.33***

⁺ = two-sided p > 0.05 (not significant), * = two-sided p < 0.05 (significant), ** = two-sided p< 0.01 (very significant), rain days are days with any recorded rainfall.

1.3.2 Land use

The region is part of the Cerrado biome, which covers nearly a quarter of the total surface area of Brazil, that is, 2.5 million km^2. The dominating natural vegetation form is savannah (Figure 1.2). Grass dominated savannah (*Campo*) is interchanging with typical tree savannah (*Cerrado*, Figure 1.4a) depending on topography and water availability (Oliveira & Marquis, 2002; Silva *et al.* 2006).

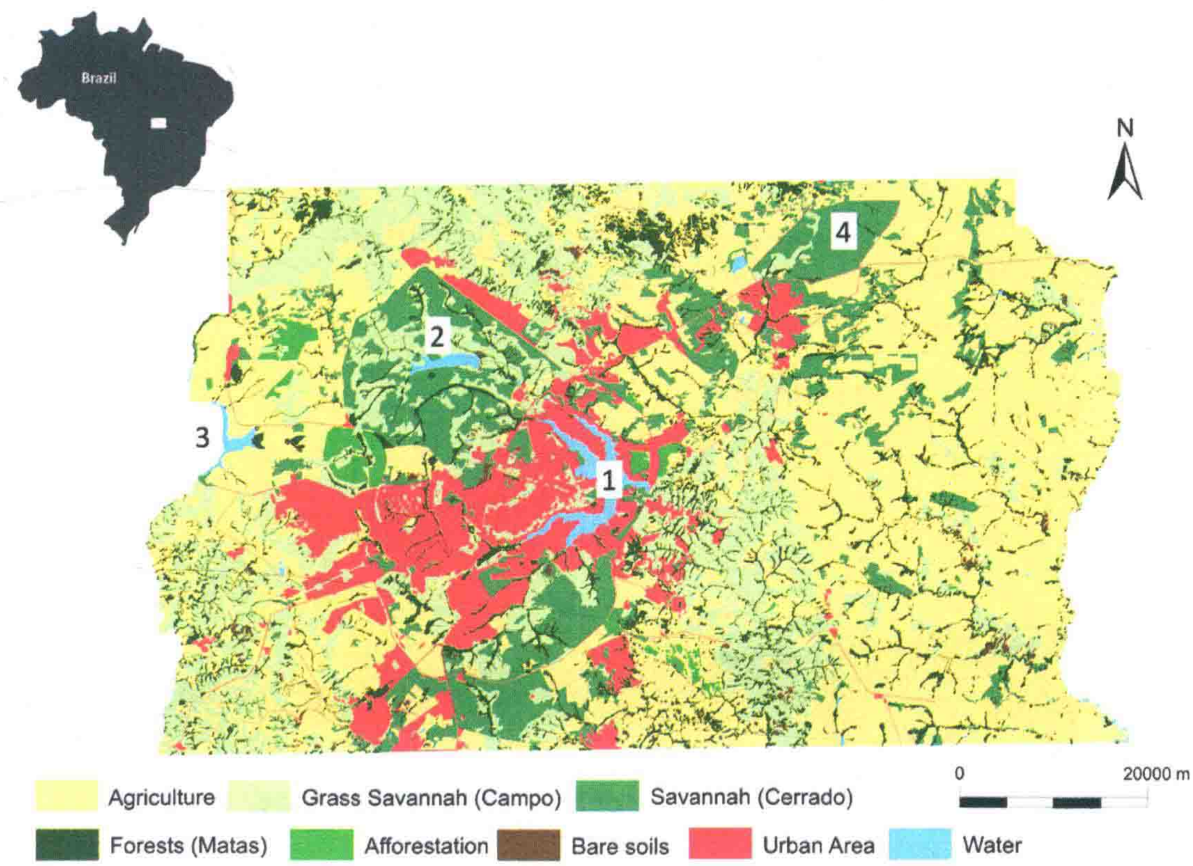

Figure 1.2 Location and land cover of the Distrito Federal in 2006, 1 = Lago Paranoá, 2 = Lago Sta. Maria, 3 = Lago Descoberto, 4 = Pipiripau (after Fortes *et al.* 2007).

Forested areas are divided in dry forests (*Cerradão*), gallery forests (*Mata de Galeria*) and pine or eucalyptus plantations. Protected areas include the National Park of Brasília – around the reservoir Santa Maria (Fig. 1.2) – and several smaller state reserves. Most of the region is covered by pastures and arable fields. Large mechanized agriculture cultivating soy bean (Figure 1.4b), corn and beans account for more than 90% of the total arable land (IGBE, 2010). Large scale crop cultivation with no-tillage practice is prevailing in the eastern part of Distrito Federal, whereas in the western part small scale farming and horticulture are dominant (Figure 1.4c). Large areas are urbanized with all development levels, that is, irregular settlements with less developed infrastructure, highly developed urban areas and residential areas with high development standards. Industrial areas do not exist in the region.

The region has experienced a substantial change in land cover and land use since the foundation of the national Capital Brasília in 1960, as it has been also observed for other regions in Brazil (Simon *et al.* 2010). Land use/cover has changed mostly due to a substantial increase of agricultural land and urban sprawl occupying mostly natural areas, that is, savannah or forest (Figure 1.3). The loss of areas with natural vegetation has been quantified with 58% for the period 1954–1998 in DF (UNESCO, 2002) which is in the same order as reported for the Cerrado biome (Klink & Machedo, 2005). The share of (semi)natural vegetation was around 40% in 2006 for the DF. From 2002 to 2007 the area of arable land (without orchards) increased by 47%, from 84,240 ha in 2002 to 123,692 ha in 2007.

Urbanization is the second major process of land use change for the Distrito Federal and is associated with urban sprawl and the spatial expansion of sealed areas. The share of urban areas increased for the period 1954 to 2001 from 0.02% to 10.62% (CODEPLAN, 2007; Fortes, 2007). The nucleus of Brasilia – finished in 1960 (Figure 1.4d, e) – is the so called *Plano Piloto* where the outlines have the shape of an airplane (in Figure 1.4d the central axis represents the fuselage). Since then, the settlement structure developed polycentric with fast growing suburbs, for example, Itapoã (Figure 1.4f). Recently, new upper standard residential areas have been developed, for example, the quarter Noroeste (Figure 1.4g).

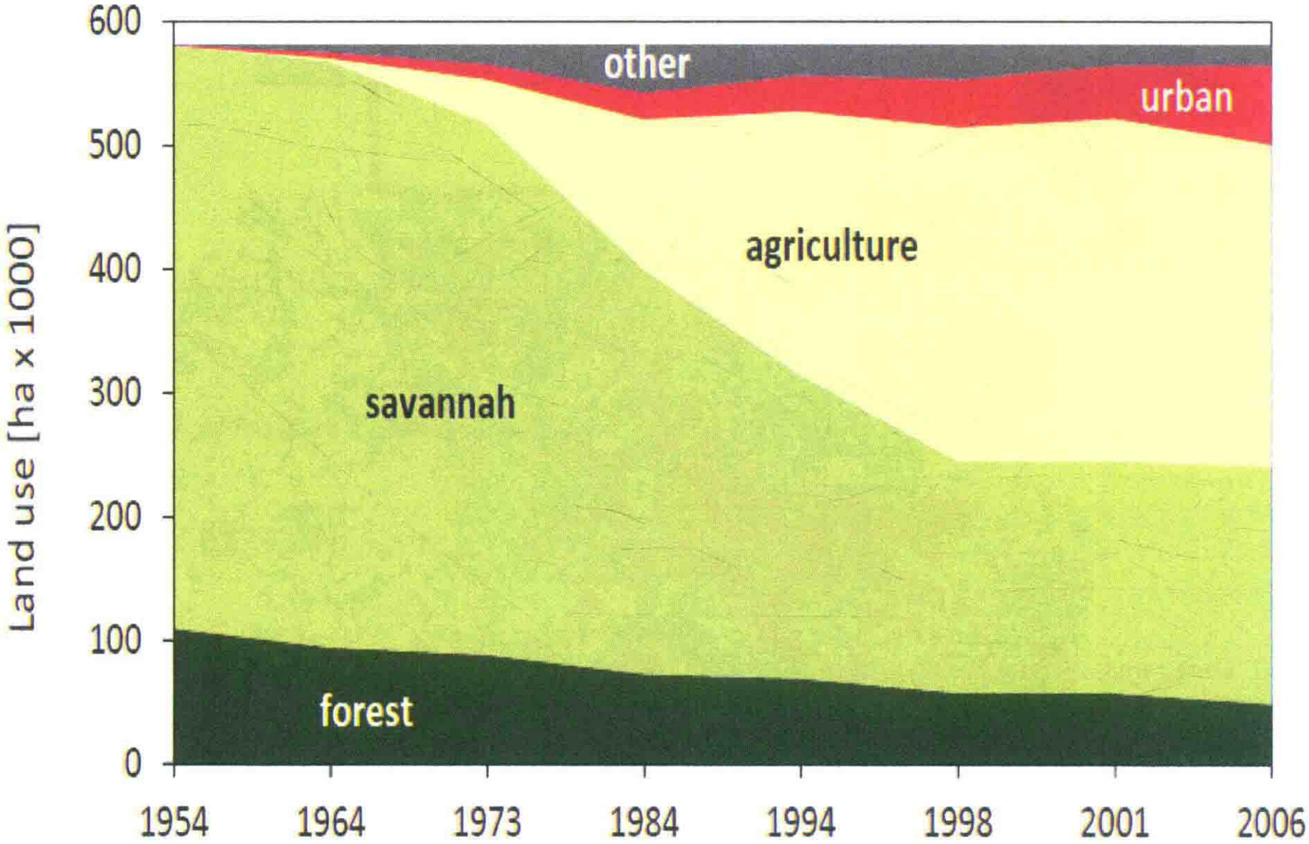

Figure 1.3 Land use change from 1954 to 2006 in the Distrito Federal (Fortes *et al.* 2007 and UNESCO, 2002).

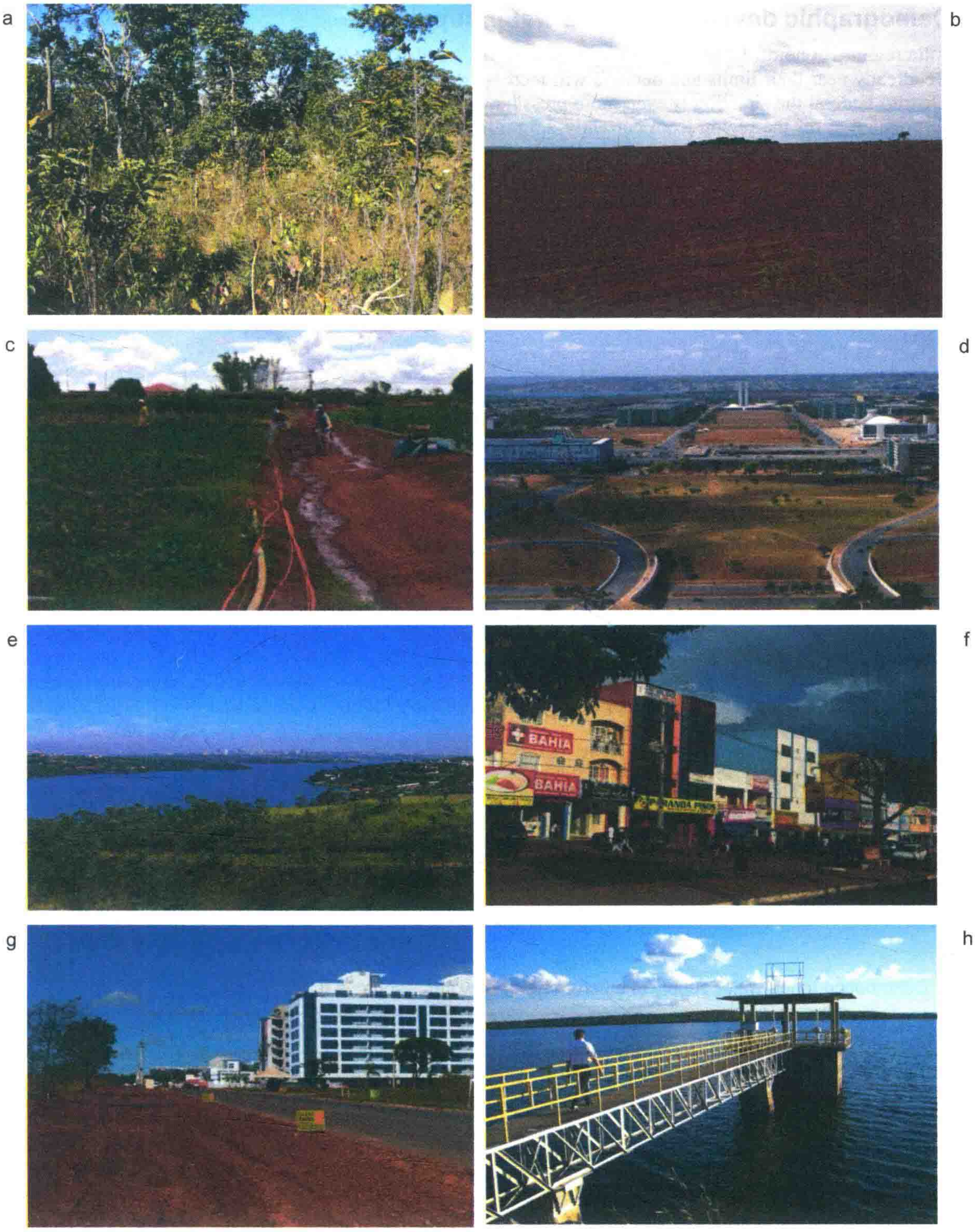

Figure 1.4 (a) tree savannah (*Cerrado*) in the national park of Brasília, (b) large scale agriculture (soy bean) in the northeastern DF, (c) irrigated strawberry fields in the western DF, (d) the central east-west axis (*Eixo Monumental*) of Brasília with buildings of the federal government and the Lago Paranoá in the left background, (e) view from southwest on Brasília, (f) commercial area in Itapoã, (g) new built residential areas in NW-Brasília (*Noroeste*), (h) water extraction site in Santa Maria reservoir.

1.3.3 Demographic development and water supply

The Brasília region is one of the large urban aggregations of Brazil where the capacities of the existing systems for water supply are already near their limits and demand will increase dramatically in the near future (ANA, 2009; CAESB, 2010). For the Distrito Federal the situation is even more pressing, since 94% of the population live in urban areas. The predicted growth of population for the region from currently 2.5 million to more than 3.2 million in 2025 will mostly take place in urban areas (Figure 1.5). Estimations of future water demand predict an exceeding of available water system capacities for the near future. During dry season the capacities for some drinking water treatment plants are already close to maximum. The average consumption per capita was in 2003 approximately 195 l d^{-1}, but minimum (110 l d^{-1}) and maximum average (597 l d^{-1}) per municipality are far apart (PGIRH, 2006).

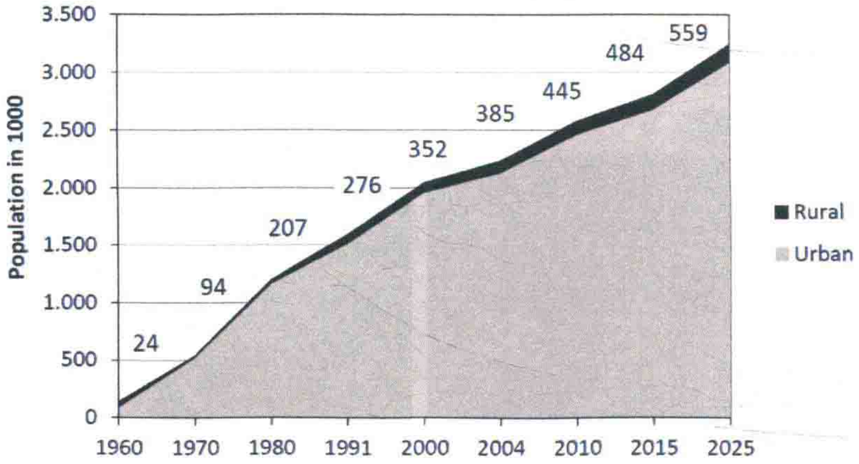

Figure 1.5 Historic and predicted population of the DF from 1960 to 2025; numbers above columns are population density (inhabitants per km^2), values for 2015 and 2025 are estimated (PGIRH, 2006).

Currently, water supply for the region is provided by two major reservoirs (Figure 1.2), Lago Santa Maria and Lago Descoberto (Table 1.2). These reservoirs cover about 78% of the total water supply of the Distrito Federal. The remaining water comes from the extraction of stream water and of groundwater. For the future, the regional water supplier CAESB is planning to extract around 2.8 m^3 s^{-1} from the Lago Paranoá, an urban lake in the centre of Brasília. An additional plan in realization is to use the reservoir Corumba IV, a reservoir for hydropower generation around 80 km to the south, for the water supply of DF. However, both lakes might have water quality problems because the respective watersheds have less adequate land use and receive waste water from settlements.

Table 1.2 Contribution to the water supply of different types of water resources (CAESB, 2003).

Type of water resource	Discharge (m^3 s^{-1})	Percentage (%)
Lago Santa Maria (area: 6 km^2, volume: 58 * 10^6 m^3)	1.9	21
Lago Descoberto (area: 14.8 km^2, volume: 102 * 10^6 m^3)	5.1	57
Stream water	1.6	18
Groundwater	0.3	4
Total water supply	8.9	100
Lago Paranoá (area: 38 km^2, volume: 498 * 10^6 m^3)	*2.8*	*(29)*

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Chapter 2

Climate change in Central Brazil[1]

P. Borges, F. D. dos Santos Silva, H. Weiss and C. Bernhofer

2.1 INTRODUCTION

The climate of the DF shows the characteristics of Central West climate, with hot and rainy summers, and dry and mild winter. Considering Köppen's classification, the region is classified as Cwa and Cwb climate. Some authors (Alves, 2009; Maia & Baptista, 2010) classify the climate as tropical wet and dry climate or Savanna climate (Aw after Köppen's classification). This climate is characterized by particular temporal distribution of temperatures and precipitation with two very well defined seasons with dry and cold winters and warm and humid summers (Alves, 2009). In average, the mean surface air temperature is 20.5°C, while rainfall amounts to 1500 mm per year (Ramos *et al.* 2009). However, more than 90% of the precipitation occurs from October to April and potential evaporation has its annual maximum in the driest months of the year, that is, June, July and August which are the months with lowest precipitation in Brasília. The high amount of annual rainfall, the heterogeneous distribution over the year and the high evaporation rates can strongly affect the water availability, especially in a water supply system which depends on surface water from large reservoirs. Nevertheless, changes in the regional climate are expected for the 21th century. The Brazilian National Water Agency (ANA, 2005) projects that the semi-arid and savanna regions in Brazil, that is, Cerrado, may face water supply crises in the coming decades. Studies on future climate scenarios of the Brazilian National Institute for Space Research (INPE; Ambrizzi *et al.* 2007) demonstrates that the Central West region may face an increase in temperature of 2 to 6°C until the end of this century. Moreover, the same study predicts a substantial increase in extreme rainfall events and droughts. Marengo (2007) describes possible impacts of climate change, for instance increase in evaporation rate and heat waves which may likely affect public health, agriculture production and hydropower generation.

Facing the urgency to take action that will guarantee the water supply of Brasília, the project IWAS-ÁGUA DF aims to contribute to the development of an Integrated Water Resources Management (IWRM) system in the region. In order to achieve this goal, the project is organized in a toolbox concept wherein climate is assumed an essential input for impact modeling (Lorz *et al.* 2012).

A systematic analysis of observed climatic variability contributes to a better understanding of the components of the regional climate in a region. However, available historical and current climate studies in Central Brazil did not provide the necessary spatial and temporal resolution for detailed climate diagnosis, as they have not satisfied the requirements for developing regional climate scenarios (Borges *et al.* 2014a). Figure 2.1 shows the general steps within the project IWAS-ÁGUA DF adopted here for developing climate scenarios. In a first step, key features of the present climate regime (i.e., Baseline) such as seasonality, spatial distribution and trends, as well as data quality, were investigated. Furthermore, GCMs can provide valuable information about climate change on a regional scale (Christensen *et al.* 2007; van der Linden & Mitchell, 2009), and therefore the output of all Global Circulation Models (GCMs) used in the Fourth Assessment Report

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