Plant and Vegetation 18

Geraldo Alves Damasceno-Junior
Arnildo Pott *Editors*

Flora and Vegetation of the Pantanal Wetland

MOREMEDIA

Springer

Plant and Vegetation

Volume 18

Series Editor
Marinus J. A. Werger, Section Plant Ecology & Biodiversity, Utrecht University, Padualaan, Utrecht, The Netherlands

Plant and Vegetation is a new Springer series comprising a series of books that present current knowledge and new perspectives on world vegetation. Examining the ecology of plants and vegetation at all scales – from plant to landscape – and covering key issues such as globalization, invasive species, climate change and the dynamics of plant biodiversity, this book series draws together a wide range of material of interest to plant ecologists, vegetation scientists, and geographers around the world.

The series provides a valuable resource for both graduate students and researchers in environmental and biological sciences, as well as for landscape planners and policy makers involved in land-use and restoration projects at local, regional and international levels.

More information about this series at http://www.springer.com/series/7549

Geraldo Alves Damasceno-Junior • Arnildo Pott
Editors

Flora and Vegetation of the Pantanal Wetland

Springer

Editors
Geraldo Alves Damasceno-Junior
Instituto de Biociências
Federal University of Mato Grosso do Sul
Campo Grande, Mato Grosso do Sul, Brazil

Arnildo Pott
Instituto de Biociências
Federal University of Mato Grosso do Sul
Campo Grande, Mato Grosso do Sul, Brazil

ISSN 1875-1318 ISSN 1875-1326 (electronic)
Plant and Vegetation
ISBN 978-3-030-83374-9 ISBN 978-3-030-83375-6 (eBook)
https://doi.org/10.1007/978-3-030-83375-6

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

I want to dedicate this book to the memory of my mother, Eunice Silva Santos (1936–2021), who was going along with me during this book realization but did not survive the pandemic to see the end. (Geraldo A. Damasceno-Junior)

Foreword

The Pantanal is one of the largest tropical floodplains in the world, with a total of circa 160,000 km^2 of which some 140,000 km^2 in Brazil. The rest is located in parts of Bolivia and Paraguay that are adjacent to the Brazilian Pantanal. The annual flooding in the Pantanal, during and following the rainy season, is mainly caused by the overflow of the rivers, and the inundation can last from about 20 to more than 270 days per year, depending on local topographic features and the amount of influx of water. Although the local differences in elevation may be rather small, they have strong impacts on the length of the period of inundation and the depth of flooding and they created strong contrasts in habitat conditions and vegetation types. Across rather short elevational gradients, strong differences in ecological conditions occur allowing "cacti to grow very near to aquatic plant species", or more accurately: patches of tropical forest and wooded savanna vegetation ("cerrado" and "cerradão") are superseded by herbaceous vegetation and still lower down by aquatic vegetation. During the dry season, fires are frequent and recurrent, favoured by low air humidity ratios and boosted by strong winds.

Though many local studies on a rather varied array of detailed inventories, and of biological and ecological features and aspects of land-use have been carried out, and the results have been published, mainly in Portuguese in specialized journals and reports, so far there was no integrated overall account of the plant growth and ecology of the Pantanal, certainly not in English. It was lucky therefore that the main editors of the present volume, Dr. Geraldo Alves Damasceno-Junior and Dr. Arnildo Pott, both of the Universidade Federal de Mato Grosso Do Sul in Campo Grande, MS, Brazil, offered to establish a large team of local specialists to create such an integrated overview of the presently existing floral and plant ecological knowledge of the Pantanal. In the following chapters the authors attend to patterns in the species composition, diversity and endemism in the flora and vegetation of the Pantanal, and discuss the biogeographical relations with the adjacent areas covered with tropical forests of the Amazon and the Atlantic coast of Brazil, with the "cerrado" and "cerradão" and the "chaco". They also point out what is known of the inundation ecology and fire ecology of the species and vegetation types, of their phenology, reproduction and seed dispersal, and they pay attention to the practical

use of the various species and vegetation types. They created a stimulating work of reference for researchers and students, well-illustrated by photographs and informative maps.

This volume was written and completed in a very disturbing period of time, with the Corona-COVID-19 virus raging fiercely in Brazil, taking the lives of many, and also twice hitting one of the main editors (GAD-J), but luckily he recovered and proceeded with this book. I congratulate the main editors and all authors with the completion of this useful book. For me it was a pleasure to work with you on this book project, and I am very pleased to present it as a volume in the series Plant and Vegetation to the international readership.

Utrecht, The Netherlands Marinus J. A. Werger

Preface

"Pantanal destroyed by flames", "Pantanal in fire" were headlines in 2020. However, is it still considered a pristine and natural wetland? The book comes at a timely moment to help to understand all that. Being a wetland, should it not be flooded? Why, how, where, and when the Pantanal burns? And will it recover?

The book is intended to be of interest to researchers, lecturers, teachers, students, botanists, biologists, ecologists, wetland scientists, environmentalists, tourists, policy makers, land managers, conservationists, and other Nature lovers.

Probably we can explain why the Pantanal is so surprising, unpredictable, and unstable, although so resilient. Not long ago, there was very little information on flora and vegetation of the Pantanal. Nowadays, numerous reports are available, but still scattered. Therefore, we invited experts on various themes related to flora and vegetation of the Pantanal to bring together the existing knowledge and our field experience to fulfill the demand for this state-of-the-art book.

Campo Grande, Mato Grosso do Sul, Brazil — Geraldo Alves Damasceno-Junior
Arnildo Pott

Acknowledgments

This book received an effective collaboration from about 50 reviewers that dedicated time to help us improve the quality of what the authors have done. We are very grateful to these reviewers since, without them, this publication would be impossible. We are also grateful to the Federal University of Mato Grosso do Sul that sponsored our work and the colleagues who relieved us of some duties during this book accomplishment. We are also grateful to the Brazilian agencies who have been supporting the research that is placed here mainly to CNPq (Brazilian National Council for Scientific and Technological Development), CAPES (Brazilian Coordination for the Improvement of Higher Education Personnel), FUNDECT (State Foundation for Science and Technology of Mato Grosso do Sul), and FINEP (Studies and Projects Financing Agency).

We also wish to thank Marinus J.A. Werger, João Pildervasser, Luciana Christante de Mello, Meenahkumary Aravaj and all the Springer editorial team for the confidence in our work and for being patient with the process of this book production that was hindered by many personal problems and the COVID pandemic.

We want to thank our families who had to undergo the process of this book construction, especially our sons.

Geraldo Alves Damasceno-Junior
Arnildo Pott

Contents

1 General Features of the Pantanal Wetland 1
Geraldo Alves Damasceno-Junior and Arnildo Pott
1.1 General Information on the Pantanal and Book Contents 1
References 8

2 Classification and Mapping of the Vegetation of the Brazilian Pantanal 11
João dos Santos Vila da Silva, Arnildo Pott, and Jô Vinícius Barrozo Chaves
2.1 Introduction 11
2.2 Main Vegetation Types 15
2.2.1 Forest Formations 21
2.2.2 Arboreal *Cerrado* 24
2.2.3 Herbaceous *Cerrado* 26
2.2.4 Chaco 26
2.2.5 Monodominant Formations 31
2.2.6 Vegetational Mixtures 33
2.2.7 Anthropic Areas 35
References 36

3 Flora of the Pantanal 39
Arnildo Pott and Vali Joana Pott
3.1 Introduction 39
3.2 Results 220
References 226

4 Aquatic Plants 229
Vali Joana Pott and Arnildo Pott
4.1 Introduction 229
4.2 Taxonomy 229
4.3 Flora of Aquatic Plants 231

4.4 Phytogeography 249
4.5 Ecology 251
4.6 Aquatic Weeds 253
4.7 Aquatic Habitats 255
4.8 Life Forms 265
4.9 Effects of Fire 266
4.10 Dispersal 267
4.11 Biology 267
4.12 Collecting Aquatic Plants for the Herbarium 272
4.13 Current and Potential Uses 274
4.14 Impacts and Conservation Status 277
4.15 Resilience 278
4.16 Final Remarks 279
References 279

5 Leguminosae in the Pantanal 289
Ângela Lúcia Bagnatori Sartori, Giovani Carlos Andrella, Luan Hernandes Pinho Nogueira, Vivian Almeida Assunção, and Thomaz Ricardo Favreto Sinani
5.1 Introduction 289
5.2 Databank on Leguminosae in the Pantanal: Procurement, Standardization, and Analyses 291
5.3 Richness and Taxonomic Distinctness 292
5.4 Knowledge Gaps and Perspectives for Studies on Leguminosae in the Pantanal 308
5.5 Final Considerations 312
References 312

6 Lichenized *Ascomycota* from the Pantanal in Mato Grosso do Sul state, Brazil 315
Luciana da Silva Canêz, Natália Mossmann Koch, Thiago Dias Barbosa, Marcos Junji Kitaura, Adriano Afonso Spielmann, Neli Kika Honda, Patrícia Jungbluth, Alice Gerlach, Robert Lücking, and André Aptroot
6.1 Introduction 315
6.2 Taxa Previously Reported from the Pantanal 317
6.3 Species Diversity and Taxonomic Treatment 323
6.4 Identification Keys 327
6.5 Identification Key to the Groups of Lichens Found in the Pantanal 327
6.6 Key A – Cyanolichens 328
6.7 Key B – Microlichens 329
6.8 Key C – Foliose Caliciaceae and Physciaceae 332
6.9 Key D – Parmeliaceae 334
6.10 Comments on the Species Treated in This Chapter 335
References 357

7 Hydrology and Vegetation Base for Classification of Macrohabitats of the Brazilian Pantanal for Policy-Making and Management 365
Catia Nunes da Cunha, Ivan Bergier, Walfrido Moraes Tomas, Geraldo Alves Damasceno-Junior, Sandra Aparecida Santos, Vivian Almeida Assunção, Ângela Lúcia Bagnatori Sartori, Arnildo Pott, Erica Cezarine de Arruda, Aurea da Silva Garcia, Rafaela Danilelli Nicola, and Wolfgang Johannes Junk
7.1 Introduction 365
7.2 The Position of the Pantanal Macrohabitat Classification Within the Brazilian Wetland Classification System: A Summary . 366
7.3 General Description of the Pantanal's Subclasses and Macrohabitats. 370
7.3.1 Functional Unit 1: Permanently Aquatic Areas 370
7.3.2 Functional Unit 2: Predominantly Aquatic Areas (ATTZ with a Predominant Aquatic Phase). 373
7.3.3 Functional Unit 3: Predominantly Terrestrial Areas (ATTZ with a Predominant Terrestrial Phase). 375
7.3.4 Functional unit 4: Swampy Areas (Permanently Waterlogged or Shallowly Flooded) 380
7.3.5 Functional Unit 5: Permanently Terrestrial Areas 381
7.3.6 Functional Unit 6: Anthropogenic Areas 384
7.4 Conclusions and Recommendations 385
References. 387

8 Monodominant Stands in the Pantanal. 393
Geraldo Alves Damasceno-Junior, Rosa Helena da Silva, Darlene Gris, Evaldo Benedito de Souza, Maíra da Rocha, Daniel Armando Manrique Pineda, Gisaine de Andrade Amador, Allan Henrique de Almeida Souza, Jens Oldeland, and Arnildo Pott
8.1 Introduction 393
8.2 Monodominant Trees and Shrubs 395
8.2.1 *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S.Moore (Bignoniaceae) – "Paratudo" 395
8.2.2 *Byrsonima cydoniifolia* A. Juss. (Malpighiaceae) – "Canjiqueira" 399
8.2.3 *Erythrina fusca* Lour. (Fabaceae) – "Abobreiro". 400
8.2.4 *Leptobalanus parvifolius* (Huber) Sothers & Prance (Chrysobalanaceae) – "Pimenteira". 402
8.2.5 *Couepia uiti* (Mart. & Zucc.) Benth. ex Hook.f. (Chrysobalanaceae) – "Pateiro". 404
8.2.6 *Vochysia divergens* Pohl (Vochysiaceae) – "Cambará" 406
8.2.7 *Curatella americana* L. (Dilleniaceae) – "Lixeira". 409
8.2.8 *Handroanthus heptaphyllus* (Vell.) Mattos (Bignoniaceae) – "Piúva" 410
8.2.9 *Inga vera* Willd. (Fabaceae) – "Ingá" 410

8.3 Monodominant Tree Palms 412
8.3.1 *Copernicia alba* Morong (Arecaceae) – "Carandá" 412
8.3.2 *Mauritia flexuosa* L.f. (Arecaceae) – "Buriti" 414
8.3.3 *Attalea phalerata* Mart. *ex* Spreng. (Arecaceae) – "Acuri" 416
8.3.4 *Attalea speciosa* Mart. *ex* Spreng. (Arecaceae) – "Babaçu" 419
8.4 Herbaceous Monodominant Formations 420
8.4.1 *Cyperus giganteus* Vahl (Cyperaceae) – "Piripiri or Piri" 420
8.4.2 *Oryza* spp. (Poaceae) – "Arroz" 423
8.4.3 *Elionurus muticus* (Spreng.) Kuntze (Poaceae) – "Capim-Carona" 425
8.4.4 *Andropogon hypogynus* Hack. (Poaceae) – "Capim-Vermelho" 426
8.4.5 *Andropogon bicornis* L. (Poaceae) – "Capim Rabo-de-Burro" 427
8.4.6 *Paspalum lineare* Trin./*Paspalum carinatum* Humb. & Bonpl. ex Flüggé (Poaceae) – "Fura-Bucho" 427
8.4.7 *Paspalum wrightii* Hitchc. and Chase (Poaceae) – "Capim Macega-Branca" 428
8.4.8 *Eichhornia* spp./*Pontederia* spp. (Pontederiaceae) – "Camalote/Aguapé" 428
8.4.9 *Typha domingensis* Pers. (Typhaceae) – "Taboa" 429
8.4.10 *Thalia geniculata* L. (Marantaceae) – "Caeté" 430
8.4.11 *Aspilia latissima* Malme (Asteraceae) – "Mirassol," "Malmequer" 430
8.4.12 *Heliconia marginata* (Griggs) Pittier (Heliconiaceae) – "Pacova" 431
8.5 Possibilities of Economical Use 431
8.6 Future Studies on Monodominant Stands in the Pantanal 433
References 433

9 Composition and Distribution of Woody and Palm Vegetation in the Pantanal Wetland 443
Evaldo Benedito de Souza, Arnildo Pott, Florian Wittmann, Pia Parolin, Heike Markus-Michalczyk, Marcelo Leandro Bueno, and Geraldo Alves Damasceno-Junior
9.1 Introduction 443
9.2 Methods 446
9.3 Results and Discussion 448
9.3.1 Altitude 448
9.3.2 Soil 449
9.4 Main Woody and Palm Vegetation Types in the Wetland and Upland Influences 451

9.5 Habitat Generalists: Species with Higher Frequencies in the Floodplain and with Wide Geographic Distributions 458
9.6 Habitat Specialists: Species with Limited Distributions in the Pantanal or That Are Restricted to Its Border. 461
References. 464

10 Natural Pastures of the Pantanal: Diversity, Productive Potential and Dynamics 471
Sandra Aparecida Santos, Evaldo Luis Cardoso, José Francisco Montenegro Valls, and Arnildo Pott
10.1 Introduction 471
10.2 Diversity of Native Pastures and Ecological Sites. 472
10.3 Productive Potential and Carrying Capacity of the Native Pastures. 474
10.4 Dynamics and Adaptative Management of the Native Pastures – A Multifunctional System. 481
References. 487

11 Woody Encroachment and Its Control in Periodically Flooded Grasslands of the Pantanal, a Large Brazilian Wetland 491
Cátia Nunes da Cunha, Fernando Henrique Barbosa da Silva, Cândida Pereira da Costa, and Wolfgang Johannes Junk
11.1 Introduction 491
11.2 Pantanal Grassland Macrohabitats Under Woody Encroachment 494
11.2.1 Shortgrass-Floodplain Community (*Campo de Mimosinho*, Sensu Schessl 1999 and Nunes da Cunha and Junk 2015) 494
11.2.2 Small Tussock Grassland (*Campos de Murundus*, Sensu Schessl 1999, Nunes da Cunha and Junk 2015) 497
11.2.3 Tall Tussock Grasslands (*Campos de Rabo de Burro*, Sensu Schessl 1999, Nunes da Cunha and Junk 2015). 497
11.3 Encroaching Woody Species in the Pantanal. 498
11.3.1 *Byrsonima cydoniifolia* A. Juss. (Malpighiaceae) 498
11.3.2 *Combretum lanceolatum* Pohl ex Eichler and *C. laxum* Jacq. (Combretaceae) 499
11.3.3 *Curatella americana* L. (Dilleniaceae) 499
11.3.4 *Vochysia divergens* Pohl (Vochysiaceae). 501
11.4 The Colonization of Grassland Macrohabitats by Encroaching Woody Plants 501
11.4.1 General Considerations 501
11.4.2 The Colonization of *Campo de Mimosinho* by *Combretum laxum*. 502

11.5 Woody Encroachment and Fauna 503
11.6 Control of Woody Encroachment: Vegetation States, Costs, History, Legal Aspects, and Current Perspectives. 504
11.7 Discussion 506
References. 508

12 Paleovegetation Inferences and Landscape Evolution in the Pantanal Basin 513
Carlos D'Apolito, Mariza Gomes Rodrigues, Barbara Fernandes Becker, and Silane Aparecida Ferreira Silva-Caminha
12.1 Introduction 513
12.2 Pollen Records in the Pantanal 515
12.2.1 Pantanal Vegetation Types and Pollen Rain. 515
12.2.2 Lake Gaiva (17°45′S, 57°35′W) 519
12.2.3 Lagoa Negra (Black Lake) (19°04′S, 57°31′W) 522
12.2.4 Porto Jofre (17°19′ S, 56°48′ W). 523
12.2.5 Salinas of Nhecolândia (18°59′ S, 56°39′ W) 524
12.3 Discussion 524
12.3.1 Potential and Obstacles of Pollen Studies in the Pantanal Basin 524
12.3.2 Late-Glacial Vegetation 527
12.3.3 Holocene Vegetation 528
12.3.4 Final Considerations and Perspectives. 528
References. 529

13 Synthesis of the Present Knowledge on Plant Phenology of the Pantanal. 535
Camila Aoki, Rogério Rodrigues Faria, Geraldo Alves Damasceno-Junior, and Arnildo Pott
13.1 Introduction 535
13.2 Methods 538
13.3 Results and Discussion 538
References. 546

14 Temporal Patterns of Pollination and Seed Dispersal in *Capões* of the Southern Pantanal. 551
Vanessa Gabrielle Nóbrega Gomes, Marlies Sazima, Rafael Arruda, Erich Fischer, and Andréa Cardoso Araujo
14.1 Introduction 551
14.2 Methods 553
14.2.1 Study Site. 553
14.2.2 Reproductive Phenology 554
14.2.3 Pollination and Seed Dispersal Syndromes 554
14.3 Results 555
14.4 Discussion 571
References. 574

15 Soil Seed Banks in the Pantanal Wetland 579
Arnildo Pott, Francielli Bao, and Evaldo Benedito de Souza
15.1 Introduction 579
15.2 Soil Seed Bank Studies in the Pantanal 580
15.3 Synthesis of Soil Seed Bank Studies in the Pantanal. 582
15.4 Effects of Flood and Fire 599
15.5 Dispersal 602
15.6 Research Needs 603
15.7 Conclusions 604
References. 604

16 Plant Morphoanatomical Adaptations to Environmental Conditions of the Pantanal Wetland 609
Edna Scremin-Dias, Jane Rodrigues da Silva, Gisele Catian, Vitoria Silva Fabiano, and Rosani do Carmo de Oliveira Arruda
16.1 Introduction 609
16.2 Effect of Flooding, Drought, and Fire on the Morphology of Aquatic Macrophytes. 610
16.2.1 Leaves: Structural and Adaptative Aspects 612
16.2.2 Stems: Structural and Adaptative Aspects 619
16.2.3 Roots: Structural and Adaptative Aspects 621
16.2.4 Adaptations of Diaspores in Aquatic Macrophytes 622
16.3 Adaptation to Flooding in Plants and Woody Seedlings 625
16.3.1 Morphoanatomical Responses of Seedlings to Soil Flooding. 626
16.3.2 Bark of Woody Riparian Forest Species 627
References. 631

17 Metabolomics Applied to Understand and Determine Ecological and Evolutionary Relationships, and Medicinal Potential of Plants from Pantanal 637
Vanessa Samúdio Santos-Zanuncio, Diomar Verçosa, Darlene Gris, Denise Brentan Silva, and Carlos Alexandre Carollo
17.1 Primary Metabolism and Secondary Plant Metabolism. 637
17.2 Metabolomics. 641
17.3 Application of Metabolomics in the Pantanal 646
17.4 The Role of Metabolomics in Chemosystematics of Pantanal Species 648
17.4.1 Effects of Environmental Factors on the Concentration of Secondary Metabolites in Early Development Stages. 651
17.4.2 Biological Activities and Nutraceutical Potential of Fruits 653
17.4.3 Future Perspectives 655
References. 655

18 Fire, Flood and Pantanal Vegetation 661
Geraldo Alves Damasceno-Junior, Alexandre de Matos Martins Pereira, Jens Oldeland, Pia Parolin, and Arnildo Pott
18.1 Introduction 661
18.1.1 Flooding 662
18.1.2 Fire 663
18.1.3 Effects of Flooding and Fire 664
18.2 Methods 665
18.3 Results and Discussion 666
18.3.1 Fire Regime 666
18.3.2 Fire and Pantanal Vegetation 672
18.3.3 Fire, Inundation, and Their Combined Effects on Vegetation 678
18.3.4 Fire, Flood, and the Management of Pantanal 682
References 684

19 Wild Food Plants of the Pantanal: Past, Present, and Future 689
Ieda Maria Bortolotto, Paulo Robson de Souza, Arnildo Pott, and Geraldo Alves Damasceno-Junior
19.1 Introduction 689
19.2 Biocultural Diversity in the Pantanal 690
19.3 Material and Methods 694
19.3.1 Historical Background 694
19.3.2 Sources of Data on Plants 696
19.4 Results 697
19.4.1 Historical Background 697
19.4.2 Wild Food Plants Used in the Past 699
19.4.3 Wild Food Plants Used in the Present and with Potential Use 715
19.4.4 *Acrocomia* spp. 716
19.4.5 *Attalea phalerata* Mart. ex Spreng 718
19.4.6 *Oryza* spp. 720
19.4.7 *Copernicia alba* Morong ex Morong & Britton 721
19.4.8 *Prosopis* spp. 722
19.4.9 *Hymenaea* spp. 724
19.4.10 *Vitex cymosa* Bertero ex Spreng. 725
19.4.11 *Victoria amazonica* Planch. ex Casp. 726
19.4.12 Other Native Food Species of the Pantanal 726
19.4.13 Future: Challenges for Conservation 730
19.5 Final Considerations 732
References 733

20 Ecological Restoration of Pantanal Wetlands 739
Letícia Couto Garcia, Letícia Koutchin Reis, Suzana Maria Salis, Angélica Guerra, Zefa Valdevina Pereira, Marcia Raquel Avalos Bogarín, and Arnildo Pott
20.1 Introduction 739
20.2 Restoration Activities in Wetlands All Over the World 740
20.3 Abiotic and Biotic Filters and Restoration in the Pantanal 741
20.4 Low Availability of Restoration Studies in the Region: Defining Gaps and Suggesting Improvements 744
20.5 Environmental Efforts for Mapping the Resilience of Brazilian Biomes and the Pantanal 745
20.6 Examples of Studies Carried Out in Brazil: Active and Passive Restoration 747
20.7 Legislation and Future Implications 759
References 761

21 Monetary Value of the Ecosystem Services of the Pantanal and Its Surroundings: First Approximations and Perspectives 767
Fábio Padilha Bolzan, Guellity Marcel Fonseca Pereira, Walfrido Moraes Tomas, Reinaldo Lourival, José Sabino, Franco Leandro Souza, Francisco Valente-Neto, Rafael Morais Chiaravalloti, Letícia Couto Garcia, Angélica Guerra, Rafaela Danielli Nicola, Áurea da Silva Garcia, Julio Francisco Alves Fernandes, Cyntia Cavalcante Santos, Mayara Camila Scur, Paula Isla Martins, Cassio Bernardino, and Fabio de Oliveira Roque
21.1 Introduction 767
21.2 Value of Natural Wetlands 768
21.3 The Pantanal and Its Surroundings 769
21.4 Estimating the Pantanal and UPRB ES Monetary Value 770
21.5 First Approximation of the UPRB ES Monetary Value 770
21.6 New Pieces of the Puzzle 773
21.6.1 Traditional Communities and Ecosystem Services 773
21.6.2 Other Values 776
21.7 Challenges, Opportunities, and Future 777
References 779

Index 785

Chapter 1
General Features of the Pantanal Wetland

Geraldo Alves Damasceno-Junior and Arnildo Pott

1.1 General Information on the Pantanal and Book Contents

The Pantanal is the world's largest continuous tropical freshwater wetland, an inland floodplain (Nunes da Cunha and Junk 2014; Assine et al. 2015c). There is some controversy on the size of the Brazilian Pantanal, depending on the criteria to define its limits; most accepted is the delimitation of 138,183 km^2 (Silva and Abdon 1998), similar to a previous estimate of 137,000 km^2 (Hamilton et al. 1996). It extends into Paraguay (5,000 km^2) and Bolivia (15,000 km^2) (Junk and Nunes da Cunha 2012). The Pantanal is part of the High Paraguay River Basin. Together with the floodplain, the Upper Paraguay basin has 496,000 km^2, including 363,442 km^2 in Brazil and 132,558 km^2 in Bolivia and Paraguay (ANA 2003). In a general way, we consider the Pantanal restricted to only the floodplain; but in socio-economics and nature conservation, the discussion about the Pantanal also encompasses the residual hills located along the Brazilian western border of the plain. These hills are much older residual relief relicts, *i.e.*, inselbergs or tops of partially buried hills (*morros*), e.g., from North to South: Solteiro, Taiamã, Caracará, Campo, Amolar, Chané, Sargento, Azeite, Comprido, Grande, Coimbra, Fecho dos Morros and Pão de Açúcar; they are connected underneath the surface to the nearby mountain ranges. These hills are surrounded by seasonally floodable areas (Fig. 1.1). In this book, most chapters use the concept of the Pantanal as only the floodplain, but some, e.g., Lichens (Chap. 6) and Wild Food Plants (Chap. 19), include information on the hills.

The Pantanal kept the old name Pantanal Matogrossense, meaning from Mato Grosso (MT), although 2/3 of the area is in the State of Mato Grosso do Sul (MS), split in 1977. Therefore, the designation Pantanal of Mato Grosso do Sul or South Pantanal is sometimes used, but we prefer to call it all just Pantanal.

G. A. Damasceno-Junior (✉) · A. Pott
Laboratório de Ecologia Vegetal, Instituto de Biociências, Federal University of Mato Grosso do Sul, Campo Grande, MS, Brazil

G. A. Damasceno-Junior, A. Pott (eds.), *Flora and Vegetation of the Pantanal Wetland*, Plant and Vegetation 18, https://doi.org/10.1007/978-3-030-83375-6_1

Fig. 1.1 Hills surrounded by the floodplain of the western border of the Pantanal

The lowland genesis is associated with the Andes uplift and associated subsidence of part of the Upper Paraguay Basin (Del'Arco et al. 1982; Ab'Sáber 1988). The basin subsidence with the first sedimentation process has begun at an undetermined time between Paleocene and Miocene (Assine et al. 2015c). The subsidence process is still in progress, and most of the sediments that nowadays cover the surface of the floodplain are from the Quaternary (Assine et al. 2015b). There are many megafans, the greatest being the Taquari megafan with circa 50.000 km^2 and up to > 400 m deep sediments. There is a discussion about the origin of these sediments, especially of the Taquari megafan. Some authors (Tricart 1982) claim an aeolian origin of this extremely high amount of sand. Nevertheless, the alleged ancient dunes were not confirmed (Irion et al. 2011), though they existed previously on the highlands.

One of the first comprehensive surveys on the Pantanal was made by the Radambrasil Project, based on radar images (Alvarenga et al. 1982). The Pantanal as a floodplain is very flat with a slope of 30–50 cm/km in the east-west direction and 3–15 cm/km in the north-south direction (ANA 2003). That is the main reason of the inundations in the region. Even being very flat, there are many regional differences, and the Pantanal is subdivided into many subregions that can vary according to the author. One of the most accepted and used subdivisions is the one made by Adámoli (1982) and modified by Silva and Abdon (1998), where the Pantanal has 11 subregions (Fig. 1.2). Other subdivisions were also made (Hamilton et al.

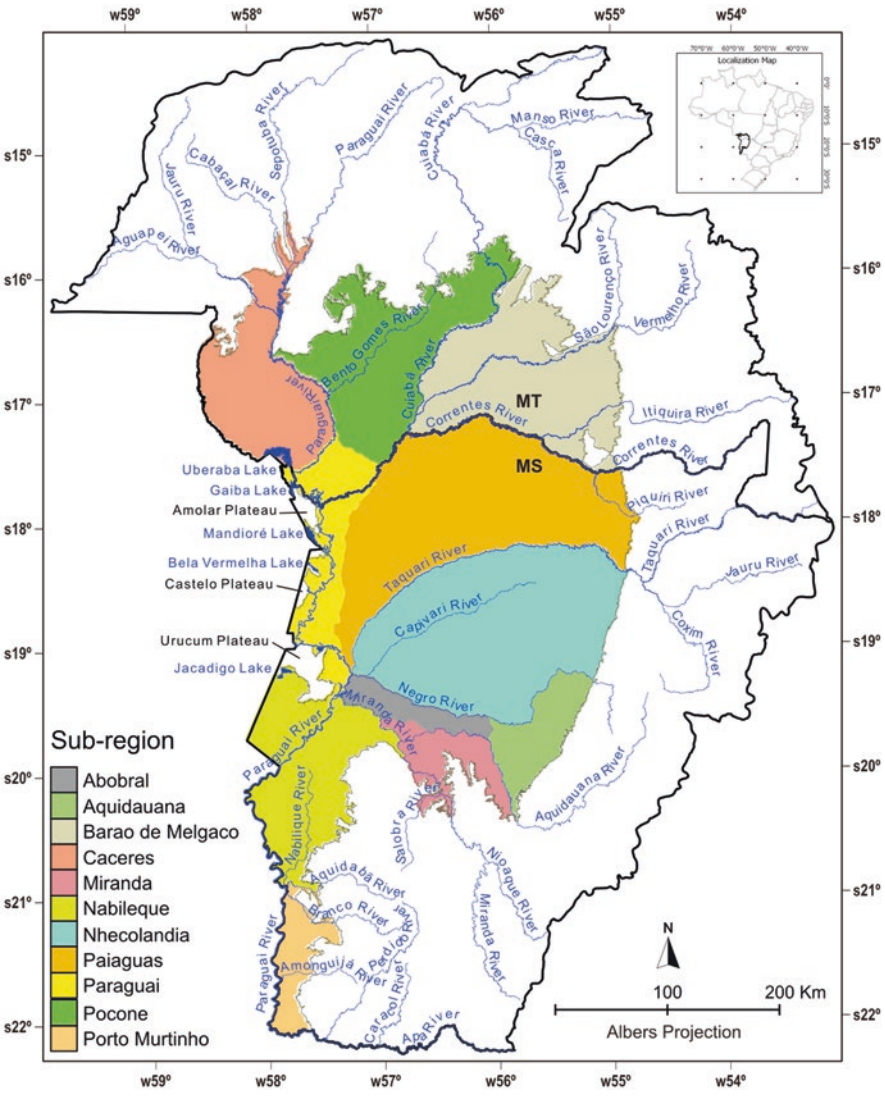

Fig. 1.2 The Brazilian Pantanal, showing its location in the map of Brazil, and its subdivision into 11 subregions and main rivers. Map by João dos Santos Vila da Silva (According to Silva and Abdon 1998)

1996; Padovani 2010). Although having many regional differences, one of the most characteristic geomorphological features of the Pantanal is the contrasts in the microreliefs on the floodplain. That is critical to the vegetation once these microreliefs can define what, where, and how long these environments can be flooded. Some important microrelief features are the paleodikes. These paleodikes receive regional names. When they have a circular or an elliptical form they are called

Fig. 1.3 Aerial photo showing the Pantanal of the Paiaguas landscape with *cordilheiras* (long-lined forested areas) and seasonally flooded grasslands. (Photo by Geraldo Alves Damasceno Junior)

capão (caa = forest and pon = rounded, in Tupy language). When the paleodikes are much longer than wide, then they are called *cordilheiras*. Curious is that *cordilheira* in Portuguese means mountain range or high hills, but here it is used to designate micro-mounds, which are mostly flood-free or flooded only in exceptional flooding (Fig. 1.3). The paleodikes were formed under paleoclimates in the Quaternary (Ab'Sáber 1988; Irion et al. 2011; Assine et al. 2015c); they originated from the lateral movement of the rivers that usually form a fluvial dike when the channel is active. These *cordilheiras*, *capões*, and riparian forests are mainly occupied by woody vegetation. A comprehensive overview of this vegetation can be found in the Chap. 9 on Woody and Palm Vegetation of the Pantanal. Information on the Flora of the whole Pantanal is given in the Checklist chapter (Chap. 3). Nevertheless, if the reader is interested in organized information on how this vegetation is distributed in the entire Pantanal; see the Chap. 2 on Vegetation and Maps. The differences in vegetation physiognomy are also most helpful to distinguish the main habitats in the Pantanal according to the flooding regime. In this book, we can find information on Macrohabitats of the Pantanal using vegetation as an indicator (Chap. 7).

The climate is seasonal Awa according to the Köppen classification (Soriano 1997). The mean annual temperature is 25ºC with maxima of 40°C. The mean annual minimum is 21°C, and the absolute minimum is around zero (Soriano 1997). Occasional frosts can also occur. The annual rainfall at the western border of the Pantanal (Corumbá) is below 1100 mm and concentrated between November and March (250–300 mm). Toward the high parts of the Upper Paraguay Basin, there is

an increment in precipitation, reaching more than 1500 mm/year (Alfonsi and de Camargo 1986; Thielen et al. 2020). The Pantanal is located within the Intertropical Convergence Zone, and this generates a circumglobal belt of climatic instability, responsible for deserts and semiarid vegetation (Marsh and Kaufman 2013). The South Atlantic Convergence Zones are responsible for most rain in the Upper Paraguay Basin (Thielen et al. 2020). The pluriannual variation in rainfall is related to La Niña and El Niño-Southern Oscillation (ENSO) and other Sea Surface Temperature Systems (SST). The primary system related to severe droughts in the Pantanal is the warming of SSTs occurring in the North Atlantic and North Pacific oceans (Thielen et al. 2020). These climatic variations can be detected in dendrochronological records (Fortes et al. 2018; Gris et al. 2020). Low rainfall means lesser flood, associated with more wildfires (see the Chap. 18 on Fire and Flood). These seasonal conditions have effects on the phenological behavior of Pantanal species and also on pollination and dispersal. Some information on species phenology can be found in the chapter on Phenology (Chap. 13) with complements on Pollination and Dispersal for *capão* vegetation (see Chap. 14 on temporal patterns of Pollination and Seed dispersal). The seasonality, sometimes dry, benefits some plant families such as Leguminosae which has the highest number of species in the Pantanal (see Chap. 5 on Leguminosae).

Rivers are avulsive in the Pantanal wetland (Assine et al. 2015a), with a monomodal flood pulse (Junk et al. 1989). The Pantanal has been considered an inland delta, as the rivers have defluents instead of affluents, i.e., inverted branching compared with a standard convergent tributary system. Thus, the main bed of rivers such as the Taquari enter the floodplain with a much larger volume than the discharge at their mouth, which is even more notorious in dry years in the Rio Negro, not flowing anymore near the Paraguay River; indeed, trees grew inside the riverbed during the very dry cycle in 1960–74. Another peculiar phenomenon is rivers running backwards when the delayed flood of the Paraguay River is higher than the water level of tributaries such as the Miranda and Negro in the dry season. The maximum area flooded was 110,000 km^2 and a minimum of 11,000 km^2 in rainy years (1979-1987) of higher floods (Hamilton et al. 1996), compared with a maximum of 52,900 km^2 and a minimum of 5,500 km^2 in 2000-2009 (Padovani 2010).

The Brazilian Navy has taken daily records of the Paraguay River level at Ladário since 1900, a valuable and much-used data set. In this database pluriannual cycles of floods and drought are noticeable (Fig. 1.4). There was a high variation in the river level from 1900 until 1960. From 1963 until 1973, the Pantanal underwent the driest recorded period. From 1974 until 2018, there was a consistent period of high inundation, and the dry spell in 2020 was consistent with the 1960s (Fig. 1.3). These variations have essential consequence in the vegetation cycles, once there are species that benefit from more inundated years, species that benefit from dry years and fire (see Chap. 18 on Fire, Flood and Vegetation), and species that need the combination of fire and flood to become monodominant (see the Chap. 8 on Monodominant Stands). These seasonal and pluriannual variations in flooding create conditions for the existence of many adaptive features in aquatic and terrestrial vegetation (see the Chap. 16 on Plant Morphoanatomical Adaptations) that can also be metabolic with

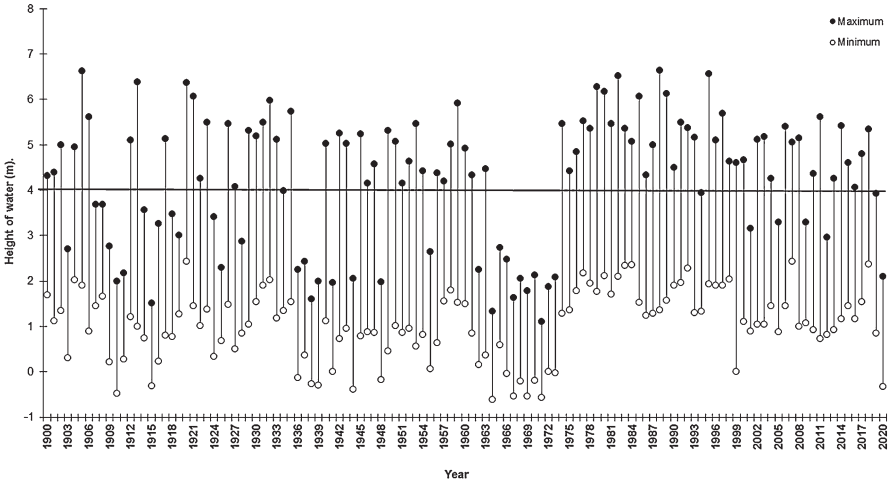

Fig. 1.4 Yearly maximum and minimum levels of the Paraguay River from 1900 to 2020 in Ladário. The 4 m line marks the upward limit for river overflow. (Data provided by the Brazilian Navy)

many compounds of secondary metabolism that can vary according to environmental features (see the Chap. 17 on Metabolomics). One striking feature of the Pantanal vegetation is that it has a flex seed bank where the dry phase activates the terrestrial species, and the aquatic seed bank is active mainly during flooding (see the Chap. 15 on Seed bank).

Most of the Pantanal is considered Aquatic Terrestrial Transition Zone (ATTZ), *i.e.*, under alternating aquatic and terrestrial phases (Junk et al. 1989), associated with various macrohabitats (Nunes da Cunha and Junk 2014) (see the Chap. 7 on Macrohabitats) and their respective vegetation types (see the chapters on Mapping (Chap. 2), Grasslands (Chap. 10), Monodominants (Chap. 8) both in the aquatic (see Aquatic Plants (Chap. 4)) and the terrestrial environments (see the Chap. 9 on Seasonal Forests).

Soils vary from oligotrophic sands on the upper parts of the alluvial fans tending to eutrophic alkaline and saline, heavy clays toward the deltas (Brasil 1982a; Brasil 1982b). Peculiar soil types are the shell-derived calcareous soil (Cunha et al. 1985), the pre-Columbian human-made earth mounds (*aterro*), and the organic histosol of floating mats (see the Chap. 4 on Aquatic Plants).

Ferns and allies were surveyed (Assis and Labiak 2009a; Assis and Labiak 2009b), though not throughout the plain. Bryophytes are not abundant in the Pantanal and yet insufficiently known (Câmara and Vital 2004; Camara and Vital 2006), and the typical wetland moss *Sphagnum* is missing (Heckman 1998). Surveys on fungi are scarce, except lichens, which became better known in the last decade (see the Chap. 6 on Lichenes).

The Pantanal plain is not very favorable to keep ancient records; in fact, it is geologically recent, except the older surrounding high terrain. However, lake

sediments have given evidence on the history of climate, fire, and vegetation (Power et al. 2016). In the limestone at Corumbá fossils of foraminifera have been found, e.g., *Corumbella werneri*, named after Corumbá, and a little horse (*Equus vandonii*). For fossil pollen, see the Chap. 12 on Palynology.

The most ancient archeological site in the Pantanal was found in the Paraguay River in Ladário with nearly 8200 years. The inhabitants at this locality were dedicated to collecting molluscs, fishing, and there are no records of ceramic or the use of plants. People lived in this location from 150 to 200 years (Schmitz et al. 2014). After that, from 6000 to 4000 ybp, there was a climatic optimum, and archeological sites that show uses of plants extensively in the floodplain. These archeological sites are embankments built with mollusc shells to escape from inundation. They can be found along rivers such as the Paraguay and Miranda and spread over the floodplain in the Abobral subregion (Schmitz et al. 2009; Peixoto and de Arruda 2015) in forest islets (*capão*), on calcareous soils (Schmitz et al. 2009). There are lithographs on the lateritic foothills of the Serra do Urucum and on the rocks of the Paraguay River margin (Schmitz et al. 2014). The use of Pantanal plants by indigenous people is documented (Oliveira 1996), and detailed information is given in the Chap. 19 on Wild Native Food Plants of the Pantanal.

For over two centuries the primary land use is traditional cattle ranching (see the Chap. 10 on Natural Grasslands) on the 95% private land, followed by fishing and ecotourism. The human population is scattered, living on cattle ranches, in tourist resorts, and in a few riverside villages; towns are only peripherical, and there are few roads and schools are scarce. The Paraguay River is utilized for navigation to transport grain, iron ore, cement, cattle, tourists, and residents. Grasslands cover most Pantanal areas (see the Chap. 2 on Maps), and the primary use of the vegetation is as native pastures where the management is made with the use of fire on tough grasses (see the Chap. 18 on Fire). The pluriannual variation in the flooding regime can promote some bush encroachment that is a challenge for the sustainable management of many native pastures (see the Chap. 11 on Encroachment). Even with the main use as native pastures, the Pantanal has undergone deforestation and that is stronger near the borders (Guerra et al. 2020). That places an extra challenge to the management, treated in the Restoration chapter (Chap. 20).

The Pantanal was declared National Heritage by the Brazilian constitution, and Natural Humanity Heritage, and Biosphere Reserve by UNESCO; however, most still is private land, except official parks and indigenous land.

National and State Parks include: Parque Nacional do Pantanal (includes the old Biological Reserve Caracará) (MT), Ecological Station Taiamã (MT), Encontro das Águas State Park (MT), Pantanal do Rio Negro State Park (MS), Park Road (MS), Baía Negra Municipal Protected Area, and Ramsar Sites (MS, MT). The main Indian reserves are Reserva Indígena Kadiwéu (in part within the Pantanal, MS), Ilha Insua (MT), and Perigara (MT).

There are a growing number of RPPNs (a legal category of conservation unit, Private Reserves of the Natural Patrimony). In Mato Grosso: Estância Ecológica SESC Pantanal (the largest, 108,000 ha), Doroché, Fazenda São Francisco do Perigara. In Mato Grosso do Sul: Acurizal, Penha, Rumo ao Oeste, Arara Azul,

Caiman Ecological Refuge, Dona Aracy, Fazenda Alegria, Fazendinha, Neivo Pires/Portal do Pantanal Sul, Nhumirim, Paculândia, Pioneira do Rio Piquiri, Poleiro Grande, Rancho Seguro, Reserva Natural Eng. Eliezer Batista, Rio Negro, Santa Cecília, Santa Sofia, and Tupaciara (Nunes da Cunha and Junk 2014; IMASUL 2021).

Despite its main economic activity as cattle ranching, this high number of private conservation units represents the high potential of the Pantanal for other economic activities still poorly developed, such as tourism. The economics and other not easily valuable aspects are also evaluated in the Chap. 21 on Ecosystem services. More about non-vegetation themes can be found in other books on the Pantanal (Junk et al. 2011; Bergier and Assine 2016). We hope that the reader may benefit from our efforts to assemble this information in a single publication and that it can be helpful to stakeholders, researchers, students, decision-makers, and the general public interested in tropical wetland vegetation.

References

Ab'Sáber AN (1988) O Pantanal Mato-Grossense e a Teoria dos Refúgios. Rev Bras Geogr 50:1–28

Adámoli J (1982) O Pantanal e suas relações fitogeográficas com os cerrados. Discussão sobre o conceito do "Complexo do Pantanal." XXXII Congr Nac Botânica 109–119

Alfonsi RR, de Camargo MBP (1986) Condições climáticas para a região do Pantanal mato-grossense. In: SIMPÓSIO SOBRE RECURSOS NATURAIS E SÓCIO-ECONÔMICOS DO PANTANAL, I. Embrapa Pantanal, Brasília, pp 29–42

Alvarenga SM, Brasil AE, Del'Arco DM (1982) Geomorfologia. In: Brasil. Ministério das Minas e Energia (ed) Projeto RADAMBRASIL. Folha SE.20. Campo Grande (Levantamento de Recursos Naturais, 28). Ministério das Minas e Energia, Rio de Janeiro, pp 125–184

ANA (2003) Implementação de práticas de gerenciamento integrado de bacia hidrográfica para o Pantanal e Bacia do Alto Paraguai-Elaboração do Diagnóstico Analítico do Pantanal e Bacia do Alto Paraguai-DAB Relatório Final Diagnóstico analítico do Pantanal e Bacia do Alto Paraguai. Brasilia

Assine ML, Macedo HA, Stevaux JC, Bergier I, Padovani CR, Silva A (2015a) Avulsive Rivers in the Hydrology of the Pantanal Wetland. In: Bergier I, Assine ML (eds) Dynamics of the Pantanal Wetland in South America. Springer Verlag, Berlin Heidelberg, pp 83–110

Assine ML, Merino ER, Do Nascimento Pupim F, De Azevedo MH, Dos Santos MGM (2015b) The Quaternary alluvial systems tract of the Pantanal Basin. Brazilian J Geol 45

Assine ML, Merino ER, Pupim FN, Warren LV, Guerreiro RL, McGlue MM (2015c) Geology and Geomorphology of the Pantanal Basin. In: Bergier I, Assine ML (eds) Dynamics of the Pantanal Wetland in South America. Springer, Berlin Heidelberg, pp 23–50

Assis ELM, Labiak PH (2009a) Polypodiaceae da borda oeste do Pantanal sul-matogrossense, Brasil. Rev Bras Bot 32:233–247. https://doi.org/10.1590/s0100-84042009000200004

Assis ELM, Labiak PH (2009b) Lycophyta from the western Pantanal, Mato Grosso do Sul State, Brazil. Acta Bot Brasilica 23:703–712. https://doi.org/10.1590/s0102-33062009000300009

Bergier I, Assine ML (2016) Dynamics of the Pantanal Wetland in South America. Springer, Berlin Heidelberg

Brasil (1982a) Folha SE.21 Corumbá e parte da Folha SE.20. Geologia, geomorfologia, pedologia, vegetação e uso potencial da terra. Vol 27. Ministério de Minas e Energia, Departamento Nacional de Produção Mineral. Projeto RADAMBRASIL, Rio de Janeiro

Brasil (1982b) Folha SF 21 Campo Grande. Geologia, geomorfologia, pedologia, vegetação e uso potencial da terra. Vol. 28. Ministério de Minas e Energia, Departamento Nacional de Produção Mineral. Projeto RADAMBRASIL, Rio de Janeiro

Câmara PEAS, Vital DM (2004) Briófitas do município de Poconé, Pantanal de Mato Grosso, MT, Brasil. Acta Bot Brasilica 18:881–886. https://doi.org/10.1590/S0102-33062004000400019

Camara PEAS, Vital DM (2006) Briófitos de Cáceres, Pantanal de Matogrosso, Brasil, con nuevos registros para el estado y el País. Bryophyt Divers Evol 27:1–8. https://doi.org/10.11646/bde.27.1.2

Cunha NG, Pott A, Gonçalves AR (1985) Solos calcimórficos da sub-região do Abobral, Pantanal Mato-Grossense. Embrapa Corumbá, Circ Técnica 19:52

Del'Arco JO, Silva RH, Tarapanoff L, Freire FA, Pereira LGM, Souza SL, Luz LG, Palmeira RCB, Tassianri CCG (1982) Geologia. In: Brasil Ministério das Minas e Energia (ed) Projeto RADAMBRASIL Folha SE. 21 Corumbá e parte da Folha SE.20 (Levantamento de Recursos Naturais, 27). Ministério das Minas e Energia, Rio de Janeiro, pp 21–160

Fortes CF, Nunes-da-Cunha C, Rosa SA, Paixão E, Junk WJ, Schöngart J, Paixão E, Junk WJ (2018) Dendrochronological records of a pioneer tree species containing ENSO signal in the Pantanal, Brazil. Brazilian J Bot 41:167–174. https://doi.org/10.1007/s40415-017-0434-8

Gris D, Paixão E, Arruda RCO, Ishii IH, Marques MR, Damasceno-Junior GA (2020) Growth and establishment of monodominant stands affected by ENSO and flooding in the Pantanal. Sci Rep 10:1–13. https://doi.org/10.1038/s41598-020-60402-x

Guerra A, Roque F d O, Garcia LC, Ochao-Quintero JM, de Oliveira PTS, Guariento RD, IMD R (2020) Drivers and projections of vegetation loss in the Pantanal and surrounding ecosystems. Land Use Pol 91:104388. https://doi.org/10.1016/j.landusepol.2019.104388

Hamilton SK, Sippel SJ, Melack JM (1996) Inundation patterns in the Pantanal Wetland of South America determined from passive microwave remote sensing. Arch für Hydrobiol 137:1–23

Heckman CW (1998) The Pantanal of Poconé, biota and ecology in the northern section of the world's largest pristine wetland. Springer, The Netherlands

IMASUL (2021) Reserva Particular do Patrimônio Natural - RPPN. https://www.imasul.ms.gov.br/reserva-particular-do-patrimonio-natural-rppn/. Accessed 11 Apr 2021

Irion G, Buchas H, Junk JW, Nunes da Cunha C, Morais JO, Kasbohm J (2011) Aspects of geological and sedimentological evolution of the Pantanal plain. In: Junk JW, Da Silva CJ, Nunes da Cunha C, Wantzen KM (eds) The Pantanal: Ecology, biodiversity and sustainable management of a large neotropical seasonal wetland. Pensoft, Sofia-Moscow, pp 47–70

Junk W, Nunes da Cunha C (2012) Pasture clearing from invasive woody plants in the Pantanal: a tool for sustainable management or environmental destruction? Wetl Ecol Manag 20:111–122. https://doi.org/10.1007/s11273-011-9246-y

Junk WJ, Bayley PB, Sparks RE (1989) The flood-pulse concept in river-floodplain systems. In: Dodge DP (ed) Proceedings of the International Large River Symposium. pp 110–127

Junk WJ, Silva CJ, Nunes da Cunha C, Wantzen KM (2011) The Pantanal: Ecology, biodiversity and sustainable management of a large neotropical seasonal wetland. Pensoft, Sofia-Moscow

Marsh WM, Kaufman MM (2013) Physical Geography. Great Systems and Global Environments. Cambrige University Press, New York

Nunes da Cunha C, Junk WJ (2014) A Classificação dos Macrohabitats do Pantanal Matogrossense. In: Nunes da Cunha C, Piedade MT, Junk WJ (eds) Classificação e Delineamento das Áreas Úmidas Brasileiras e de seus Macrohabitats. EdUFMT, Cuiabá, pp 83–130

Oliveira JE (1996) Guató: Argonautas do Pantanal. EDIPUCRS, Porto Alegre

Padovani CR (2010) Dinâmica Espaço-Temporal Das Inundações Do Pantanal. Esc Super Agric "Luiz Queiroz" Cent Energ Nucl na Agric 174

Peixoto JL, de Arruda AA (2015) Interação regional dos grupos indígenas pré-coloniais que ocuparam a região das Grandes Lagoas do Pantanal e da Chiquitania. In: Alconini S, Betancourt CJ (eds) En el corazón de América del Sur 3 (Arqueología de las tierras bajas de Bolivia y zonas limítrofes). Imprenta 2E, Santa Cruz de la Sierra, pp 41–66

Schmitz PI, Rogge JH, Rosa AO, Beber MV, de Freitas EAV (2009) Aterros da Tradição Pantanal nas fazendas Sagrado Coração de Jesus e Bodoquena, Corumbá, MS. Pesqui Antropol 67:321–374

Schmitz PI, Rogge JH, Beber MV, Rosa AO (2014) Arqueologia do Pantanal do Mato Grosso do Sul - Projeto Corumbá. Tellus 0:11–26. https://doi.org/10.20435/TELLUS.V0I1.2

Silva JSV, Abdon MM (1998) Delimitação do Pantanal brasileiro e suas sub-regiões. Pesq. Agropec. Bras. 33:1703–1711

Soriano BMA (1997) Caracterização climática de Corumbá. Embrapa-CPAP (Bol. de Pesquisa, 11), Corumbá. 25p

Thielen D, Schuchmann KL, Ramoni-Perazzi P, Marquez M, Rojas W, Quintero JI, Marques MI (2020) Quo vadis Pantanal? Expected precipitation extremes and drought dynamics from changing sea surface temperature. PLoS One 15:1–25. https://doi.org/10.1371/journal.pone.0227437

Tricart J (1982) El Pantanal: un ejemplo del impacto geomorfologico sobre el ambiente. Inf Geogr 29:81–97

Chapter 2
Classification and Mapping of the Vegetation of the Brazilian Pantanal

João dos Santos Vila da Silva, Arnildo Pott, and Jô Vinícius Barrozo Chaves

2.1 Introduction

This chapter connects with most other chapters, such as Flora (Chap. 3), Aquatic Plants (Chap. 4), Monodominants (Chap. 8), Native Grasslands (Chap. 10), Phenology (Chap. 13), Fire and Encroachment (Chap. 18).

The Pantanal is a geologically young (Quaternary) sedimentary plain, which undergoes variable inter- and intra-annual flooding, caused by local rain or river overflow (Silva et al. 2003). Owing to its dimensions, the Pantanal is considered the largest continuous floodplain of inland waters (Silva and Abdon 1998). This plain is located in the Upper Paraguay River Basin (UPRB), in the Brazilian Central-West region, in the centre of South America, most of the area laying in Brazil, and smaller parts in Bolivia and Paraguay (Silva et al. 2003).

Several studies dealt with the delimitation of the Pantanal in Brazil, standing out Silva and Abdon (1998), who mapped the UPRB (361,666 km^2) and the Pantanal floodplain (138,183 km^2) considering the aspects of floods, relief, soils, and vegetation (Fig. 2.1). However, IBGE (2004) delimited the Pantanal as a biome (150,335 km^2), a divergence arisen from different conceptual criteria, field observations, and the adopted scale. The term "biome" is considered by the governmental

J. dos Santos Vila da Silva (✉)
Embrapa Agricultura Digital, Pesquisa & Desenvolvimento, Campinas, SP, Brazil
e-mail: joao.vila@embrapa.br

A. Pott
Laboratório de Ecologia vegetal, Instituto de Biociências, Universidade Federal de mato Grosso do Sul, Campo Grande, MS, Brazil

J. V. B. Chaves
Pós-graduação em Sistema de Infraestrutura Urbana, Pontifícia Univesidade Católica de Campinas Rua João Bissoto Filho, Valinhos, SP, Brazil

G. A. Damasceno-Junior, A. Pott (eds.), *Flora and Vegetation of the Pantanal Wetland*, Plant and Vegetation 18, https://doi.org/10.1007/978-3-030-83375-6_2