

The landscape-scale structure and functioning of floodplains

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To Sammy and Dan
without whom this would be meaningless

Abstract

Floodplains are amongst the most productive and biodiverse ecosystems. The structure and functioning of floodplains is controlled by the interaction of intermittent inundation with the floodplain landscape. These interactions create highly complex and dynamic ecosystems that are difficult to study at large scales. Consequently, most research of floodplains has been conducted at small spatial and temporal scales. Inundation of floodplains can extend over many square kilometres, however, which unifies the floodplain landscape into an integrated ecosystem operating at the landscape scale. The lack of data and poor understanding of the landscape-scale structure and functioning of floodplains limits the possibility of managing floodplains sustainably as pressure for exploitation of their resources increases.

This thesis quantifies the landscape-scale relationship between the frequency and patterns of inundation, the composition and structure of the landscape, and the functioning of the floodplain landscape in terms of the distribution and dynamics of plant growth vigour over an area of approximately 376,000 ha on the Lower Balonne Floodplain; highly biodiverse, semi-arid floodplain ecosystem that straddles the state border between New South Wales and Queensland approximately 500 km inland from the eastern coast of Australia. Mean annual rainfall at St. George, to the north of the study area, is approximately 400–450 mm per year, and median annual evaporation is approximately 2000 mm per year. Plants and animals on the floodplain are therefore heavily dependent upon flooding for survival.

This project is based on the analysis of 13 Landsat Thematic Mapper satellite images captured over a 10-year period during which land and water resource development increased substantially. There is now concern that development activities have affected the functioning of the floodplain to the detriment of the natural environment and

agricultural productivity. The impacts from these activities on the functioning of the floodplain are not yet known, however.

Inundation of the Lower Balonne Floodplain was mapped using a two-part process involving a band ratio to identify deep clear water, and a change detection analysis to identify areas of shallower inundation. This analysis shows that, in contrast with most floodplains, the main flowpath of the Lower Balonne Floodplain runs along its central axis away from river channels, which flow along the floodplain's outer edges.

Inundation propagates from the centre of the floodplain out towards river channels as flood discharge volumes increase.

Variations in the spatial pattern of inundated patches within the inundated extent create distinctive aquatic habitat and connectivity conditions at different flow levels. These can be described in terms of three connectivity phases: (I) Disconnected, in which isolated patches of inundation occur at low flows and river channels are hydrologically dislocated from the floodplain; (II) Interaction, where increased hydrological connectivity between inundated patches, and between the floodplain and the river channels at moderate flows, may enable significant exchange of materials, organisms and energy; and (III) Integration, in which almost the entire floodplain landscape is connected by open water during large magnitude floods.

There is an abrupt transition in inundation patterns as flows increase between 60,000 ML day⁻¹ and 65,000 ML day⁻¹ (ARI 2 to 2.3 years) in which inundation patterns transform from being relatively disconnected into a highly integrated network of patches. These patterns may have significant consequences for the structure and functioning of the floodplain. Increases in flows across this small range may therefore mark an important ecological flow threshold on this system. Water resource development impacts have changed the relative frequency of flows on the Lower

Balonne Floodplain, which will probably affect the sequence of connectivity phases over time. The most likely impact of these changes will be to create a floodplain that is drier overall than under natural flow conditions, and that has a smaller and wetter area of high inundation frequency.

The relationship between inundation and the structure of the floodplain landscape was examined by comparing a landcover map showing the distribution and character of 10 landcover types to the inundation frequency maps. Landcover types were mapped from a multi-date Reference Image composite of seven images captured over a period of 10 years. The Reference Image improves landcover discrimination by at least 14% over classification of a single-date image, and has an overall accuracy between 82.5% and 85% at the landscape-scale. The Reference Image shows that the landscape of the Lower Balonne Floodplain is a highly fragmented mosaic of diverse landcover types distributed in association with inundation frequency. Stratifying the floodplain into zones of frequent and rare inundation shows that frequently inundated areas have a less fragmented but less diverse landscape structure than rarely inundated areas. Assessment of the functioning of each landcover types within the floodplain ecosystem, based on landscape pattern metric analysis, indicates that the function of landcover types also changes between inundation frequency zones. Most importantly, these changes include a transformation of the matrix landcover type, which controls the character and dynamics of the ecosystem overall, from Open Grassland to Coolibah Open Woodland in the frequently inundated zone.

The landscape structure of the Lower Balonne Floodplain has been affected by development impacts, which include clearing of native vegetation, isolation of parts of the floodplain from natural inundation events by the construction of levee banks and drainage channels, and grazing impacts. Changes to the inundation regime may also

affect the structure of the floodplain landscape. Over the long term, these changes are likely to create a larger area of Open Grassland and a smaller area of Coolibah Open Woodland as the zone of frequent inundation becomes smaller and wetter.

To examine the functioning of the floodplain ecosystem, the inundation maps were compared to remotely sensed indexes of plant growth vigour at the landscape and landcover-type scales. The dynamics of plant growth vigour over time are influenced by factors operating at the regional, landscape and patch scales. Evaporation is the major control of growth vigour levels at the landscape scale, but each landcover type has a distinctive pattern of growth vigour dynamics that is related to its composition and location, and possibly its landscape structure. The association between the spatial distribution of plant growth vigour and inundation frequency is non-linear, with the highest growth vigour occurring where inundation occurs approximately once per year. This indicates a subsidy-stress interaction with water in which plant growth vigour is limited by soil anoxia in areas of frequent or long term inundation, and by drought stress in rarely inundated areas.

A landscape-scale model of growth vigour dynamics, founded on the principles of Hierarchical Patch Dynamics and Landscape Ecology, was created from growth vigour measurements of each landcover type over time. This model was used to examine possible impacts of development activities on the functioning of the floodplain ecosystem. This model shows that the response of plant growth vigour development activities can be complex and subtle, and include a change in mean long-term growth vigour and an increased susceptibility to drought. The model also indicates that periods of high growth vigour can occur in substantially altered floodplain ecosystems. The model was also used to explore the levels of landcover change that might cause a threshold change in the functioning of the ecosystem, which may substantially alter the

disturbance-response characteristics of the floodplain ecosystem. The model indicates a threshold change when the extent of Open Grassland is reduced by 30% of its extent in 1993, in which plant growth vigour response to disturbance is virtually inverted from that observed in the images. The temporal variability of plant growth vigour levels increases as the extent of Open Grassland is further reduced.

This thesis makes a number of important contributions to our understanding of floodplain structure and functioning. It includes the development of new techniques suited to studying large diverse and complex landscapes at the landscape scale from satellite images, and provides quantitative data describing the links between the structure of floodplain landscapes and their functioning at the landscape scale. This work improves the understanding of floodplain ecosystems by integrating models of floodplain structure and functioning, which have been developed largely from smaller-scale studies of temperate and tropical floodplains, with landscape-scale measurements of this semi-arid system. This thesis also has implications for the Lower Balonne Floodplain by improving the level of information about this important ecosystem and providing baseline data against which the condition of the floodplain can be assessed in future.

CERTIFICATE OF AUTHORSHIP OF THESIS

Except where indicated in footnotes, quotations and the bibliography, I certify that I am the sole author of the thesis submitted today entitled 'The Landscape-Scale Structure and Functioning of Floodplains'. I further certify that to the best of my knowledge the thesis contains no material previously published or written by another person except where due reference is made in the text of the thesis. The material in the thesis has not been the basis of an award of any other degree or diploma except where due reference is made in the text of the thesis. The thesis complies with University requirements for a thesis as set out in

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Preface

A preliminary version of part of this work was published in:

Sims, N. C. and Thoms, M. C. (2002) What happens when floodplains wet themselves: vegetation response to inundation on the Lower Balonne Floodplain. **In:** *Proceedings of the IAHS Symposium on the Structure, Function and Management Implications of Fluvial Sedimentary Systems, Alice Springs, September 2002*. International Association of Hydrological Sciences. p 195-202.

This paper is included in this thesis as Appendix A.

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TABLE OF CONTENTS

Chapter 1. Introduction	1
1.1. The need for this research	1
1.2. The focus of this thesis	1
1.2.1. Aims and objectives.....	4
1.2.2. Précis	5
Chapter 2. The structure and functioning of floodplains	7
2.1. What are floodplains?	7
2.1.1. Inundation.....	7
2.1.2. Geomorphology	8
2.1.3. Vegetation.....	10
2.1.4. Floodplain landscapes.....	11
2.2. Studying floodplains at the landscape-scale	11
2.2.1. A hierarchy of scales for floodplain studies	12
2.2.2. Remote Sensing	14
2.3. Key issues in the landscape-scale assessment of floodplains	20
2.3.1. Conceptual models of floodplain structure and functioning.....	21
2.3.2. Inundation patterns	26
2.3.3. Landscape structure	30
2.3.4. Plant productivity	33
2.3.5. Dryland floodplains	36
Chapter 3. The Lower Balonne Floodplain	38
3.1. Location	38
3.2. Climate.....	39
3.3. Hydrology	40
3.3.1. River channels	40
3.3.2. Flow variability.....	42
3.3.3. Anecdotal flow/inundation relationships.....	44
3.3.4. Groundwater	44
3.4. Topography	45
3.5. Landcover	46
3.6. Fauna.....	48
3.7. Land use	49
3.8. Summary.....	52

Chapter 4. Image data and pre-processing	53
4.1. Image data.....	53
4.2. Image pre-processing	56
4.2.1. Geometric rectification.....	57
4.2.2. Radiometric correction	58
4.3. Summary.....	60
Chapter 5. Inundation patterns	61
5.1. Introduction.....	61
5.2. Materials and methods	62
5.2.1. Inundation mapping.....	62
5.2.2. Inundation modelling.....	64
5.2.3. Flood frequency analysis.....	64
5.2.4. Pattern metric calculation	65
5.3. Results.....	68
5.3.1. Resource development impacts on flows	68
5.3.2. Inundation modelling.....	69
5.3.3. Inundation distribution	70
5.3.4. Inundation frequency.....	70
5.3.5. Inundation patterns	75
5.4. Discussion.....	78
5.4.1. Flood Pulses.....	78
5.4.2. Hydrological connectivity	80
5.4.3. The impact of resource development.....	83
5.5. Summary.....	84
Chapter 6. Landscape structure	86
6.1. Introduction.....	86
6.2. Materials and methods	88
6.2.1. Landcover mapping.....	88
6.2.2. Pattern metric calculation	92
6.3. Results.....	94
6.3.1. Character and distribution of landcover types.....	94
6.3.2. Map accuracy assessment.....	98
6.3.3. Landscape structure	100
6.3.4. Structure differences between inundation frequency zones	102
6.3.5. The impacts of land resource development	105

6.4. Discussion	107
6.4.1. The character and distribution of landcover types.....	107
6.4.2. Landscape structure	108
6.4.3. Resource development impacts	110
6.5. Summary	113
Chapter 7. Plant growth vigour	115
7.1. Introduction.....	115
7.2. Materials and Methods.....	117
7.2.1. Vegetation index selection.....	117
7.2.2. Productivity/inundation frequency measurement.....	120
7.2.3. Temporal variations in growth vigour	120
7.3. Results.....	121
7.3.1. Spatial distribution of plant growth vigour.....	121
7.3.2. Temporal dynamics.....	124
7.3.3. Threshold transformation	132
7.4. Discussion.....	133
7.4.1. Plant productivity and inundation frequency.....	133
7.4.2. Temporal dynamics of productivity levels	135
7.4.3. The impact of resource use activities.....	137
7.5. Summary.....	140
Chapter 8. Conclusion	142
8.1. Summary.....	142
8.2. Implications of this thesis	147
8.2.1. Image processing and analysis.....	147
8.2.2. Quantification of floodplain structure and functioning at the landscape scale.....	148
8.2.3. The Lower Balonne Floodplain.....	152
8.3. Recommendations for future studies.....	153
References	155
Appendix A: Sims and Thoms, 2002	185
Appendix B: Previews of Landsat images used in this thesis	193

LIST OF FIGURES

Figure 1. Hypothesised distribution of plant productivity levels in relation to flood frequency as predicted by the Subsidy-Stress Hypothesis (Odum <i>et al.</i> , 1979; Odum <i>et al.</i> , 1995).....	25
Figure 2. Rivers, flow gauging stations and major towns of the Lower Balonne Floodplain, southern Queensland, Australia.....	38
Figure 3. Median monthly Balonne River discharge, rainfall and evaporation at St.George. ...	40
Figure 4. Jack Taylor Weir on the Balonne River at St.George.	41
Figure 5. Total daily Balonne River discharge at St.George between 2 October 1971 and 31 August 1999 annotated with the generalised flood levels described in Section 3.3.3.....	43
Figure 6. An illustration of the flatness of the floodplain.....	45
Figure 7. A shallow channel of Brairie Creek in the lower mid-section of the study area.....	45
Figure 8. A typical expanse of rarely inundated grassland with pale soils.....	46
Figure 9. Black cracking soils in an area of frequent inundation.....	47
Figure 10. The dense riparian forest that flanks river channels throughout the floodplain.....	48
Figure 11. Part of a large water storage in the floodplain's central region.....	50
Figure 12. Total daily Balonne River discharge at St.George in the 90 days before capture of each image.....	56
Figure 13. Landsat TM image captured on 19 January 1993 (TM bands 1,7,4 as BGR). This image was chosen as the base image to which other images were spectrally and geometrically corrected.	57
Figure 14. Pixel brightness (digital numbers) of PIF targets in TM band 4 in the images captured on 19 January 1993 and 5 February 1999, (A) before image calibration and (B) after calibration.	59
Figure 15. Total area of inundation versus peak daily discharge in the 14 days before image capture.....	71
Figure 16. The distribution of inundation at four Qp14 discharge volumes.....	73
Figure 17. Flood frequency distribution across the Lower Balonne Floodplain. Flood ARI zones have been grouped for display.	74
Figure 18. Correlations between Qp14 discharge and the pattern of inundation for different parameters of inundation shape.....	77
Figure 19. Diagrammatic description of the method of creating the Reference Image.	89
Figure 20. The distribution of zones of rare and frequent inundation.....	93
Figure 21. The distribution of landcover types on the Lower Balonne Floodplain mapped from the Reference Image composite of Landsat TM images.	95

Figure 22. The proportion of annual flood recurrence zones occupied by each landcover type	98
Figure 23. Spectral signatures for selected landcover types.	99
Figure 24. The reduction in size of landcover types from conversion to agricultural land uses between 19 January 1993 5 February 1999.....	106
Figure 25. River flows and rainfall between the dates of image capture and biomass sampling in April and May 1999.	118
Figure 26. Spatial distribution of NDVI levels across the Lower Balonne Floodplain	122
Figure 27. NDVI class composition in zones of rare and frequent inundation.....	123
Figure 28. NDVI class composition of ARI zones.	123
Figure 29. Variation in mean landscape-scale NDVI over time.	124
Figure 30. NDVI dynamics over time for a subset of landcover types.....	126
Figure 31. A comparison of the mean whole-floodplain NDVI dynamics measured from the images and the modelled NDVI data.	128
Figure 32. Comparison between modelled mean whole-floodplain NDVI dynamics and NDVI dynamics modelled on: (A) 50% reduction of Coolibah Open Woodland; (B) 50% reduction of Open grassland; and (C) the distribution of landcover types predicted from changes to the flow regime of the Balonne River at St.George (Chapter 5).	131
Figure 33. The influence of incremental reductions in Coolibah Open Woodland and Open Grassland, from their extent in 1993, on the standard deviation of landscape-scale NDVI values over time.	133

LIST OF TABLES

Table 1. Objectives and research questions addressed in this thesis.....	4
Table 2. Hierarchical scales related to the landscape-scale characteristics of floodplains (adapted from Forman, 1995a; 1995b; Ward, 1998a; Ward <i>et al.</i> , 2002a; Ward <i>et al.</i> , 2002b).	14
Table 3. The characteristics of some commercially available remote sensing systems.....	16
Table 4. Characteristics of some key conceptual models in river-floodplain ecology.	22
Table 5. Defining features and functional characteristics of landscape elements in the patch- corridor-matrix model of landscape ecology.....	31
Table 6. Daily, monthly and annual discharge percentiles (ML) for the Balonne River at St.George between 2 October 1971 and 31 August 1999.	43
Table 7. Landsat Thematic Mapper spectral bands used in this thesis	53
Table 8. Images used in this study, including the hydrologic and climatic conditions before image capture.	55
Table 9. Inundation pattern metrics measured for this analysis.....	66
Table 10. Modelled Balonne River discharge at St George showing current flows as a proportion of natural flows.....	68
Table 11. Spearman’s correlation coefficients between river flow and climatic data used in inundation modelling. Peak, median, mean and total discharge over the respective periods before image capture were compared to the extent of inundation in each image, as well as Evaporation (Evap30) and Rainfall (Rain30) in the 30 days before image capture.....	69
Table 12. Patterns of inundation mapped from each image.....	72
Table 13. Flow levels and inundation patterns of inundation phases.....	81
Table 14. Balonne river discharge and rainfall at St George before image capture for the Landsat TM images used in this project.	88
Table 15. Landscape pattern metrics measured in this analysis.....	92
Table 16. Plant and soil composition of landcover types and their spatial characteristics.	96
Table 17. Classification accuracy comparison of the Reference Image and single-date images used in this project.....	101
Table 18. Classification accuracy confusion matrix (number of pixels) for landcover types mapped from the Reference Image.	101
Table 19. Landscape scale metrics for the entire Lower Balonne Floodplain	103
Table 20. Landcover type scale metrics for the entire Lower Balonne Floodplain	103
Table 21. Landscape scale metrics for zones of rare and frequent inundation	104

Table 22. Difference in landscape scale pattern metrics between inundation frequency zones. A positive value indicates an increase in the frequently inundated zone and a negative value indicates a decrease in the frequently inundated zone.....	104
Table 23. Spearman’s correlation coefficients between vegetation indices calculated from the image captured on 26 April 1999 and total grassland plant biomass sampled from 14 to 22 May 1999.	119
Table 24. NDVI summary statistics for landcover classes.	127
Table 25. Spearman’s correlation coefficients between landscape-scale pattern metrics and NDVI variables	127
Table 26. Beta coefficients and the intercept for each landcover type in the ‘no change’ regression model.	129
Table 27. NDVI characteristics of the measured pattern of dynamics and the ‘no-change’ regression model.	129
Table 28. Beta coefficients for each landcover type in modelled scenarios	130
Table 29. NDVI characteristics of the modelled resource use impact scenarios.	130
Table 30. Results and implications of this study	143