Culture and environmental relational values at Amazonian farm-forest frontiers

Jordan Omar Blanchard Lafayette

Lancaster Environment Centre, Lancaster University

This thesis is submitted for the degree of Doctor of Philosophy

September 2025

Envision
Developing next generation leaders in environmental science

University of Nottingham
UK | CHINA | MALAYSIA

INEAF
Instituto Amazônico de Agriculturas Familiares
30 anos

Lancaster Environment Centre | Lancaster University

"Amazonia is changing rapidly and, as is the case in other areas of heightened social conflict, the character of change is matter of disagreement. What is curious about change in Amazonia is that social forces always seem to be playing second fiddle to 'natural' ones. The angle on deforestation, widely covered in the non-specialist press, is always about trees, not land-tenure. Road-building is about erosion or food chains, not about agrarian reform. 'Threatened species', a call-to-arms for many campaigning bodies, does not necessarily extend into the upper reaches of the animal kingdom."

(Stephen Nugent, Big Mouth: The Amazon Speaks, 1990:2)

Abstract

Large-scale tropical deforestation threatens biodiversity, global climatic stability, and the livelihoods of forest-dependent people. The Brazilian Amazon harbours tremendous cultural diversity, rooted in Indigenous cosmologies, forest management practices, and centuries of adaptations by Amazonian peasantry. Yet annual deforestation has been high for decades, driven primarily by agricultural frontier expansion, characterized by violent dispossession of forest-dependent communities by illegal loggers and cattle ranchers. Quantitative analyses have focused on economic, spatial and political factors, largely neglecting the role of culture in land-use decisions. In contrast, ethnographic work demonstrates that forest clearance for pasture coincides with the emergence of an Amazonian *cattle culture*.

This thesis examines the relationship between culture and regional-scale environmental change, investigating how cultural expression and environmental relational values are associated with land-use and land-cover change (LULCC) at deforestation frontiers. I employ novel demographic approaches to quantifying cultural expression at large-spatial scales, analysing 3,427 songs played on 1,069 local radio stations across the Brazilian Amazon to perform the first cross-sectional culture~environment study to my knowledge. To link cultural expression and relational values to environmental histories and rural modes of production thousands of kilometres apart, I conducted fieldwork in four municipalities, ranging from one with 98% remaining forest cover and few cattle to another with 73% forest remaining and over 2.4 million cattle, the largest herd in Brazil. I developed and administered a novel survey to rural and urban people in each municipality, examining cultural expression associated with traditional Amazonian identities, cattle culture, and people's relationships with their local environment.

My results demonstrate that cultural identities and relational values across Amazonia are highly heterogenous and are associated with local land use, migration histories, and frontier expansion. I show that deforestation has complex and significant cultural dimensions and provide evidence that cattle culture is displacing traditional forest cultures as deforestation transforms landscapes. Recognising the cultural dimensions of LULCC in Amazonia is therefore critical to protecting forests and cultures of forest-proximate people who have underpinned people-centred conservation in Brazil and elsewhere.

Contents

Abstract iii

List of Figures viii

List of Tables x

List of Chapter Appendices xii

List of Chapter Covers xiv

Acknowledgements xv

Author's Declaration xvii

Statement of contributions of others xvii

Chapter 1: Introduction 1

1.1 Overview 2

1.2 Case Study: Brazilian Amazon 7

1.2.1 History of deforestation across the Brazilian Amazon 7

1.2.2 Cattle ranching 8

1.2.3 The role of cattle in daily Amazonian life 10

1.3 Key concepts of this thesis 12

1.3.1 Inconsistencies in defining 'Culture' 12

1.3.2 Cultural expression 14

1.3.3 The role of culture in land-use and land cover change 15

1.3.4 Cattle culture 16

1.3.5 Relational values 18

1.3.6 Frontiers in the Brazilian Amazon 20

1.3.7 Space-for-Time Approaches 21

1.4 Key knowledge gaps 22

1.5 Aims and Contributions of the Thesis 23

1.5.1 Thesis Structure Outline 24

1.5.2 Research Journey and Reflections 25

1.5.3 Researcher Positionality 26
Chapter 2: Country music popularity on local radio-stations is associated with cattle and forest loss across the Brazilian Amazon 31
Abstract 32
2.1 Introduction 33
2.2 Methods 38
2.2.1 Study Area 38
2.2.2 Data Sampling 39
2.2.3 Data Analysis 41
2.3 Results 46
2.4 Discussion 61
2.4.1 Linking cattle ranching and the prevalence of Sertanejo music on local radio stations 62
2.4.2 Sertanejo popularity reflects historical forest loss, not recent deforestation 63
2.4.3 Sertanejo popularity is associated with declining cultural (musical) diversity 65
2.4.4 Study Limitations 67
2.5 Conclusion 68
Chapter 3: Cultural expression at Amazonian deforestation frontiers 71
Abstract 72
3.1 Introduction 73
3.1.1 Traditional land uses support Amazonian biocultural diversity 75
3.1.2 Cattle culture in Amazonia 78
3.1.3 Political ecology of frontiers, ecological and cultural loss 79
3.2 Methods 82
3.2.1 Study Area 82
3.2.2 Data Sampling 92
3.2.3 Survey Instrument 96

3.2.4 Instrument validation, factor analysis, and worth scores 97
3.2.5 Data Analysis 99
3.3 Results 101
3.4 Discussion 115
3.4.1 Deforestation and linkages with Amazonian culture and cattle culture 117
3.4.2 Migration status and cultural expression 119
3.4.3 Study Limitations 121
3.5 Conclusion 122
Chapter 4: Between cattle and canopy: Relational values in the Brazilian Amazon 125
Abstract 126
4.1 Introduction 127
4.1.1 Complexity of relational values 131
4.1.2 Key knowledge gaps around relational values 133
4.2 Methods 136
4.2.1 Study Area 136
4.2.2 Data Sampling 138
4.2.3 Survey Instrument 138
4.2.4 Survey Validity 140
4.2.5 Data Analysis 143
4.3 Results 148
4.4 Discussion 161
4.4.1 Relational values are linked to social-ecological context 163
4.4.2 Rurality and relational values 166
4.4.3 Local land-cover and relational values 167
4.4.4 Policy implications 168
4.4.5 Study Limitations 170
4.5 Conclusions 170

Chapter 5: Concluding Remarks 172
5.1 Key findings 173
5.2 The complex relationship between forest loss, cattle, and culture 174
5.2.1 How do forms of cultural expression change across deforestation frontiers? 177
5.2.2 How are relational values associated with deforestation and landscape change? 178
5.3 To what extent is cultural change at frontiers associated with migration? 179
5.4 Future directions 180
5.4.1 Empirical study of culture at large spatial scales 180
5.4.2 Relational values in Global South contexts 180
5.4.3 The role of religion in shaping environmental values and cultural expression 181
5.4.4 Institutional links between agriculture and cultural dissemination 182
5.4.5 Environmental Governance and Policy Recommendations 184
Appendices 188
References 212

List of Figures

Figure 2.1 - Satellite imagery (ArcGIS Pro, ESRI, 2025) showing land-use and land-cover of the Legal Amazon biome ……..….. 38

Figure 2.2 - PCoA ordination plot of municipality clusters with arrows displaying musical genre distance based on municipal musical preference profiles based on song identification from local radio stations …….……...… 48

Figure 2.3 - Hierarchical clustering of musical genres across municipalities, shown as a dendrogram with a hierarchy cutoff of 0.77 based on ward distance matrix..…….…….…..... 49

Figure 2.4 - Spatial hotspots and cold spots of Sertanejo country music played on local radio stations across 335 municipalities in eight sampled Amazonian states.…….…….…….….. 51

Figure 2.5 - Bubble plot of Sertanejo songs as a proportion of all songs recorded (per municipality) plotted against the proportion of original forest remaining (in 2023)…. 53

Figure 2.6 - Spatial hotspots and cold spots of cattle herd sizes across 335 municipalities in eight sampled Amazonian states ..…….……...…. 55

Figure 2.7 - Boxplot of Sertanejo country music song counts, separated by cattle (2019, Log+1 head of cattle) hotspot categories....…….…….……. 56

Figure 2.8 - Predicted relationship between municipal cattle herd size (log-transformed) and the number of Sertanejo songs observed on local radio, with 95% confidence intervals. ....…….…… …….……...…….. 59

Figure 3.1 - Examples of traditional daily practices that are formed and reinforced by a dependence of peasant societies on forests, rivers and lakes in the Brazilian Amazon. 77

Figure 3.2 - The five themes of cattle culture (Hoelle, 2015, pp 149-150) …….. 79

Figure 3.3 - Location of the study regions in Brazilian Legal Amazon, municipalities and detailed land-cover information of each municipality where surveys were undertaken, indicating the location of 407 sampled households …….……...…….. 90

Figure 3.4 - Urban area maps for each municipality separated by frontier stage: a) Pre-frontier (Tefé); b) Early frontier (Lábrea); c) Intermediate frontier (São Félix do Xingu); and d) Late frontier (Paragominas) ...……..…… …. …. ……..….. 91

Figure 3.5 - Boxplots of culture factor scores separated by frontier stage, colour coded by municipality, shown from pre-frontier (Tefé, AM) on the left to late frontier (Paragominas, PA) ...……..…… …. …. . ……...…… 105

Figure 3.6 - Mean factor scores and standard error bars for both traditional Amazonian culture factor scores (subplot a) and cattle culture factor scores (subplot b) …..….... 108

Figure 3.7 - Traditional Amazonian factor and cattle culture factor questions and response frequencies (Bottom) from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages ……..….. 109

Figure 3.8 - Violin plots with grouped boxplots illustrate the variation in cultural expression scores between Amazonians and non-Amazonians in São Félix and Paragominas (intermediate and late-stage frontiers) ……..…… 111

Figure 4.1 - Examples of environmental contexts across Amazonia in which relational values may be formed ……..……...….. 129

Figure 4.2 - Environmental values expressions (shared across three categories of values [relational, intrinsic and instrumental values]), adapted from Figure 5, Himes *et al.* (2024), p. 33 ……..……..……...….. 130

Figure 4.3 - Boxplot of relational environmental values factor scores separated by deforestation frontier stage, colour coded by municipality . ……...….. 149

Figure 4.4 - Mean factor scores for four kinds of relational values (Forest Utility, Forest Identity, Cattle Utility, Cattle Identity) across four deforestation frontier stages and urban/rural sub-populations in the Brazilian Amazon …….…....…. 153

Figure 4.5 - Pro-forest utility associated RVs questions and response frequencies in São Félix do Xingu and pro-cattle identity and importance associated RVs questions and response frequencies in pre-frontier Tefé and São Félix do Xingu from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages 156

Figure 4.6 - Modelled effects of higher relative land cover (log ratio of compositional land-use data) of forests and cattle pasture for four relational value factor scores .. 158

List of Tables

Table 2.1 - Popular musical genres (top 10) played on radio stations in 335 municipalities in the Brazilian Amazon..…….. 46

Table 2.2 - Correlation matrix showing the correlation (Spearman's Rho) and p-value (Bonferroni adjusted) between count of Sertanejo songs played on local radio stations and incremental deforestation between 2021 and 2023, including total cumulative deforested area (km²)..…… 52

Table 2.3 - Correlation matrix demonstrating correlation between count/proportion of songs that were Sertanejo songs, Cattle herd sizes and Pasture area (km2) between 2019 - 2023. …… 54

Table 2.4 - Model results for GLM Negative Binomial Control Model (Model #2). Coefficient estimates with standard errors, Z, p-values of significance, IRR and corresponding 95% confidence intervals ……..……..… 57

Table 2.5 - Model results for GLM Negative Binomial Spatial Autocorrelation Model (Model #3). Coefficient estimates with standard errors, Z, p-values of significance, IRR and corresponding 95% confidence intervals all reported ……..… 59

Table 2.6 - Reporting of ANOVA tests comparing nested Sertanejo ~ Cattle Model #1, Model #2, and Model #3 ……..……..……..……..…. 60

Table 3.1 - Rates of recent deforestation, percentage of original forest that had been lost by 2024, and total cumulative deforested primary forest (km2) between 1986 - 2023 by surveyed municipality……..……..……..…….……..…. 86

Table 3.2 - Urban area split of each municipality for population size, urbanised area, municipality size ……..……..……..……..…….……..…. 92

Table 3.3 - Confirmatory Factor Analysis (CFA) model comparisons with included survey items, factor loadings and model fit indices ...……..…….……..... 103

Table 3.4 - Descriptive statistics (mean ± SE) of traditional Amazonian culture and cattle culture factor scores across frontier stages ...……..…….……..….. 106

Table 3.5 - Descriptive statistics (mean ± SE) of traditional Amazonian culture and cattle culture factor scores across rural and urban areas between frontier stages … 108

Table 3.7 - Estimated mean (± SE) of traditional Amazonian culture and cattle culture factor scores between Amazonian and non-Amazonian respondents ……..…… 110

Table 3.8 - Robust Standard error linear regression models of traditional Amazonian and cattle culture factor scores ...……..…….……..…….…… 112

Table 3.9 - Robust standard error linear model of Amazonian factor scores including socio-economic covariates (Control Model #1) …….……..…….…… 113

Table 3.10 - Robust standard error linear model of Cattle culture factor scores including socio-economic covariates (Control Model #2) …….……..…….…… 114

Table 4.1 - Relational environmental values factors representing pro-forest and pro-cattle values of utility and identity/importance …….……..……..…… 143

Table 4.2 - Univariate linear model expected means for relational value factor scores per frontier stage and the standard error based on 95% confidence intervals ……... 150

Table 4.3 - Descriptive statistics (mean ± SE) of traditional Amazonian culture and cattle culture factor scores across rural and urban areas between frontier stages … 151

Table 4.4 - Robust Linear Model results comparing effects of rural and urban settlement across frontier stages on relational values factor …….……..……..……. 155

Table 4.5 - Summary of simple linear and Clustered standard error linear model results predicting pro-forest relational value factor scores ….……..……..……. 160

Table 4.6 - Summary of simple linear and Clustered standard error linear model results predicting pro-cattle relational value factor scores ….……..……..……. 161

List of Chapter Appendices

List of Supplementary Figures

Supplementary Figure 2.1 - Histogram of unique genre counts per municipality … 188

Supplementary Figure 2.2 - Correlogram of musical genres identified from online radio stations in 335 municipalities in the Brazilian Amazon …..……..……. 188

Supplementary Figure 2.3 - Shannon index scores per municipality based on musical diversity, where higher Shannon index scores refer to higher diversity …….……. 189

Supplementary Figure 2.4 - Scatterplot showing the correlations between the proportion of Sertanejo songs recorded per municipality, and (a) the Number of migrants per 100 citizens; and (b) the Log Euclidean distance to the nearest municipal capital of at least 100,000 inhabitants ……. 189

Supplementary Figure 3.1 – Recent deforestation activity (2019-2024) across each municipality: a) Pre-frontier (Tefé, Amazonas); b) Early frontier (Lábrea, Amazonas); c) Intermediate frontier (São Félix do Xingu, Pará); and d) Late frontier (Paragominas, Pará) ……..…….……..……..……..…….…….……. 192

Supplementary Figure 3.2 - Location of the study regions in Brazilian Legal Amazon, municipalities and detailed land-cover information of each municipality where surveys were undertaken, indicating the location of Conservation Units (UC) and Indigenous Territories (TI) in each municipality …..……..……..…….……..…. 193

Supplementary Figure 3.3 - Correlogram of Food Protein Consumption and Taste rankings by respondents ..…….……..……..……..…….……..…. 194

Supplementary Figure 3.4 - Traditional Amazonian factor and cattle culture factor questions and response frequencies from ‘Completely Disagree (1)’ to ‘Completely agree (5)’, split by rural and urban frontier stages …….…… 194

Supplementary Figure 4.1 - Two-Factor omega model for pro-forest RVs ……..… 200

Supplementary Figure 4.2 - Two-Factor omega model for pro-cattle RVs ……..… 200

Supplementary Figure 4.3 - Spearman correlations between relational values factor scores and local land-use cover within a 3.14km² area around rural households ….. 201

Supplementary Figure 4.4 - Pro-forest utility, identity and pro-cattle utility, identity associated RVs questions and response frequencies from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages ……..…… 202

Supplementary Figure 4.5 - Linear model predictions showing variation in relational values factors across the deforestation frontier stages …….……..…… 204

Supplementary Figure 4.6 - Forest cover (as a percentage of total land cover) within a 1km radius of rural surveyed households …….……..… 204

List of Supplementary Tables

Supplementary Table 2.1 - Number of songs observed per unique genre observed across data collection in all municipalities ……..…….…….…..... 190

Supplementary Table 2.2 - Number and Percentage of Survey Respondents from surveys that listen to local radio stations at least 'some of the time' …….…… 191

Supplementary Table 2.3 - Self-reported Religious Identity of Survey Respondents (See Chapter 3 (Culture)) that listen to Gospel Music often (responded '4 = Often'; or '5 = All The Time') ……..……..…..……..…….…..…..... 191

Supplementary Table 3.1 - Survey questions for Socio-economic and demographic characteristics; and cultural expression survey questions ……...…..…… 195

Supplementary Table 3.2 - Exploratory factor analysis model comparisons with factor loadings for each survey item ……... …….…..…. 197

Supplementary Table 3.3 - List of respondents (total numbers and percentages of total responses) that were born in the same municipality they currently live in, born elsewhere in the same state, born in a different Amazonian states, and born outside of the legal Amazon …….…….……..… 198

Supplementary Table 3.4 - Top five municipalities of origin for all respondents per frontier stage (municipality) ……...…….…..… 199

Supplementary Table 4.1 - Subscale groupings of survey questions for Pro-Forest and Pro-Cattle RV survey questions ……...…..…….…..…. 205

Supplementary Table 4.2 - One-Factor vs Multi-Factor Confirmatory Factor Analysis model comparisons with included survey items, factor loadings and model fit indices for pro-forest and pro-cattle RVs subscale models 206

Supplementary Table 4.3 - Kruskal-Wallis non-parametric test for significant differences between medians of factor scores across frontier stage 209

Supplementary Table 4.4 - Dunn Kruskal-Wallis multiple comparison Z-scores, p-values, and p-adjusted with Bonferroni correction 209

Supplementary Table 4.5 - Kruskal–Wallis non-parametric test for significant differences in factor score distributions between urban and rural settlements within each municipality 211

List of Chapter Covers

Sai daqui, pó! i

Rio Amazonas 1

Pé do Castanha 30

Feira do Açaí 70

Ficar à Sombra 124

Rio Marajó-Açu..... 172

O Pesquisador 187

All chapter covers (including the title page) are based on photographs I took during rural fieldwork in Brazil (2022, 2024). These images were subsequently modified with the assistance of ChatGPT-5 (2025) to resemble linocut art.

Acknowledgements

Like many achievements, this PhD is not mine alone, but the culmination of persistence shaped by the support, encouragement, patience, and ultimately, love of others.

Thank you to my supervisors, who have contributed tremendously. To Dr. Luke Parry, who saw the potential in me when I was unable to see it in myself, and whose love for the Amazon and Brazil has afforded me transformative experiences. To Dr. Chris Ives, who kept me grounded, and whose encouragement has facilitated my personal and professional growth. To Dr. Jeff Hoelle, who welcomed me to and partially funded my exchange trip to UCSB in 2023, while providing much needed critical guidance on culture. And to Prof. Dr. Valério Gomes, who hosted me at INEAF in 2022 and 2024, helping me to get settled and offering invaluable guidance from a Brazilian Amazonian perspective.

I was supported by a studentship from the Natural Environmental Research Council (NERC). Thank you to Envision DTP staff and students for an unforgettable PhD.

This thesis also owes its existence to multiple people in Brazil, to whom it seems most fitting to thank in Portuguese: Agradeço aos pesquisadores e pós-graduandos do INEAF, especialmente à Profa. Dra. Monique Medeiros e ao Prof. Dr. Mauro Silva, que me acolheram no departamento de braços abertos. Às secretarias de Lábrea, Tefé, Paragominas e São Félix do Xingu. Um enorme agradecimento aos ACS de toda a Amazônia, sem os quais a coleta de dados na zona urbana não teria sido possível, mas especialmente aos ACS de Chico Breves, Lábrea: *Eliete, Deusdélia, Gerente Dened*, e tantos outros nos postos de saúde, que acolheram este gringo Jamaicano nervoso em suas cidades e em suas casas. Obrigado à Marcikely, Sebastiana e Antônio da ASPACS, e à Dra. Heloísa Pereira e ao Dr. Danny Tregidgo do Instituto Mamirauá, assim como às dezenas de comunidades rurais que participaram desta pesquisa e me acolheram em suas casas. E aos meus excelentes e dedicados assistentes de pesquisa, Paula, Gustavo, Ray e Paulo, que ajudaram imensamente na coleta de dados e se tornaram colegas e amigos. Por fim, agradeço aos incríveis amigas e amigos que fiz no meu tempinho no Brasil - Ana, Michelle, Lene, Nathan, e tantos outros. Espero vê-los em breve. Atenciosamente, seu ‘Jamaica do Brasil’.

This thesis has benefitted from the help and guidance of many great researchers in Lancaster and Nottingham. In LEC, I thank the Tropical Forests group who have also become good friends. To *Mãe do Campo*, Juliana, for guiding and supporting me in Paragominas; To Nath and Leo for GIS guidance; and Cássio for coding and statistical advice. *Vou sentir falta de vocês, Ein?!* Thank you also to Jos and Cecília for unreservedly welcoming me into the group, and to Dr. Nick Claire, Karla, and Luísa for helping me navigate the social aspects of research in Latin America and feel part of the postgraduate community in Nottingham too.

Enormous thanks go to the many friends I have met along the way. To Katie, to whom I have been attached at the hip with since we started our PhDs, whether in Nottingham for coffee or for Teams study sessions across Oceans. To Camila and Fernando, who introduced me to *o jeito Brasileiro*. To Reuben, Justin and the REED network, who helped me find a place to belong in academia. To Joe, Nadia, Cristina, and Vinolia of Primrose - I will miss you all dearly. To my Human Geography officemates, Mayur, Jingran, and Touhid, for keeping me sane. To Lauri-Li, for brunches and weekend office grinds. To Rachel, for life chats and meme sharing. And of course, to the brilliant friends I've had since day one, such as Luke, Kuda, Vivya, Akaash, and many others who've showed unwavering support and love since my Ellis and Bilborough days.

Thank you to my family. They say it takes a village to raise a child, and I hope you are proud of the man you helped raise. To my Grandmother, whose love for learning inspired my own pursuit. To my Uncle Amaan and Auntie Nicky, who showed me the value of discipline, consistency and mindfulness in the pursuit of one's goals. To my Uncle Shaun and Auntie Sandra, who encouraged me to be authentic to myself. To my cousins: Iman, Leila, Rafael and Rosa, who are more like siblings. To Shaun and the Harrison family, for your encouragement throughout. To Ashlee, who is like a big sister to me. To Auntie Sam and Uncle Stu, my biggest supporters. And to my Grandad, who I hope would be proud of the person I've become. None of this would have been possible without your collective support and encouragement from day one. *We run tings, tings nuh run We!*

Finally, to my amazing Mum - I stand on your shoulders. As I grow further into adulthood, I understand less and less how you managed to raise me on your own. My only hope is that this achievement does justice to your sacrifices. Thank you.

Author's Declaration

This thesis is my own original work and has not been submitted in part or in full for the award of a higher degree anywhere else. All inputs from co-authors and collaborators have been acknowledged throughout.

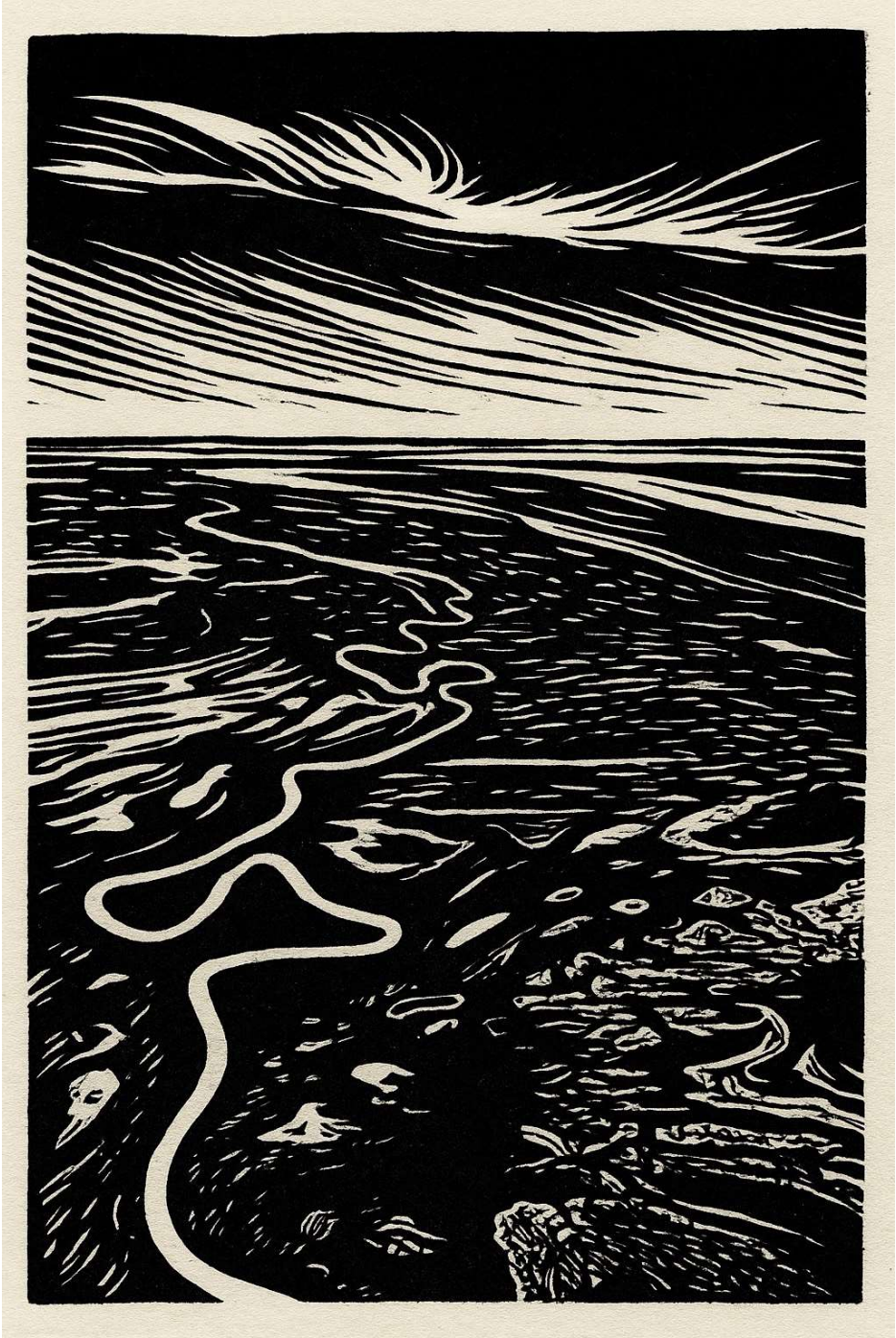
Jordan O. Lafayette, September 2025

Statement of contributions of others

This thesis includes collaborations with my supervisors, Luke Parry, Chris Ives (University of Nottingham), Jeffrey Hoelle (University of California, Santa Barbara, USA) and Valério Gomes (Federal University of Pará, Brazil). Each chapter in this thesis reflects collaborations with several other co-authors. I collected most of the data presented, but I acknowledge that **Chapter 2** and **Chapter 3** include data that was also collected by my field assistants during fieldwork in 2024: Paula Vasconcelos Leite at the Federal University of Amazonas; Sebastiana Arruda de Lima at ASPACS, Lábrea; Gustavo Roberto Coelho at the Federal University of Amazonas; Maria Raimunda Nascimento at Federal Institute of Pará, Paragominas; and Paulo Gomes Santos at the Federal University of the South and South-East of Pará, São Félix do Xingu (in chronological order of data collection).

All collaborator contributions are acknowledged, and their contributions have been outlined on the title page of the relevant chapter. I developed the research questions and experimental design of the radio station study (conducted in 2023) and structured field survey (conducted in 2024) projects (with input from all supervisors at various stages), analysed data, and synthesized into manuscripts for publication. My supervisors provided guidance on study design, and field and editorial support. This PhD was funded through the Envision Doctoral Training Programme (DTP) by Natural Environmental Research Council (NERC). Additional funding support was provided by Jeffrey Hoelle through the Fullbright Commission to facilitate a research visit to Santa Barbara in 2023.

Chapter 1: Introduction



"It seems to me that the natural world is the greatest source of excitement; the greatest source of visual beauty; the greatest source of intellectual interest. It is the greatest source of so much in life that makes life worth living."

Sir David Attenborough

1.1 Overview

Tropical rainforests are among the most vital ecosystems on planet Earth, playing a central role in regulating the planet's climate while also sustaining an unparalleled diversity of life (Flores *et al.*, 2024). Intact tropical rainforests are vital reservoirs of carbon that capture and store the atmospheric greenhouse gases that drive global warming (Allen *et al.*, 2000). Concurrently, the tremendous biological richness of many rainforests drives ecological stability at local to planetary scales, while supporting cultural foundation and livelihoods of millions of people worldwide (Newton *et al.*, 2020), including in Amazonia (Parry *et al.*, 2025). However, these forests are at the vanguard of human-driven change. Deforestation, ecological degradation, and instability resulting from this change threaten not only ecological functioning and stability of rainforests, but also the critical planetary processes they underpin (Barlow *et al.*, 2018). Understanding the dynamics of human-driven change and the associated consequences is therefore essential in addressing the multiple and intertwined crises of biodiversity loss, climate change, and the loss of habitats that have supported people for tens of thousands of years (Brondizio, 2025).

The Brazilian Amazon is the most biodiverse rainforest on Earth (Ribas *et al.*, 2025), yet Amazonia's richness extends far beyond ecology. It is also home to vast cultural diversity, which encompasses hundreds of Indigenous groups and languages, diverse cultural practices, and knowledge systems that have co-evolved with forests for millennia (Heckenberger *et al.*, 2007), constituting the immense biocultural diversity of the biome (Otamendi-Urroz *et al.*, 2025). Far from popular depictions of the Amazon as a pristine, untouched area of wilderness (Nugent, 1995), its landscapes and biodiversity have been shaped by traditional management practices (such as agroforestry, controlled burning, and the domestication and dispersal of keystone species) (Levis *et al.*, 2018). These practices encouraged and enhanced traditional ecological knowledge, while supporting flourishing biodiversity across the biome, and have ultimately sustained human livelihoods long before colonial conquest (Cleary, 2001; Nascimento, Aukes and McMichael, 2024). These complex and profound human-nature relationships have given rise to unique cosmologies and worldviews that are often in stark contrast to developmentalist ideals that underpin much federal governance across the tropics (Gould, Martinez and Hoelting, 2023), as well as international governance perspectives

that have targeted financial interventions for forest-proximate people, such as REDD+ (Fletcher *et al.*, 2016; Skutsch and Turnhout, 2020).

Although Indigenous cultures are highly heterogeneous, they are distinct from Brazilian Amazonian peasant cultures, which are also shaped by forest proximity and dependence (Schmink, 2003). Amazonian peasant cultures are hereafter defined as the diverse lifeways and social formations of smallholder farmers, extractivist, and rural labourers in the Brazilian Amazon, whose livelihoods are historically shaped by a blend of subsistence production, participation in regional and local markets, and complex relations with state, capital, and nature (Hecht and Cockburn, 1989). Traditional peasant communities have an extensive history of forest-dependent livelihoods and cultural identifications with rainforests (Schmink *et al.*, 2008), yet, until Nugent's (1993) pioneering work, they went largely unstudied by anthropologists in favour of Indigenous histories (Nugent, 2009). This has coalesced with larger political and economic structural imbalances in Brazil's social hierarchy, meaning that Amazonian forest communities have been *invisible* – in that they have not been seen or had their views and struggles substantively recognized or valued (Adams *et al.*, 2009) – and have historically been denied secure land tenure, making these communities vulnerable to dispossession and ejection by more powerful actors and interests, including the state (Fraser, 2018). Importantly, peasant societies (and not indigenous populations) comprise most rural-dwelling populations in the Amazon Basin. For instance, Parry *et al.* (2025) estimate that while the total rural population in the Brazilian Amazon is 9.11 million people, only 404,950 people live in Indigenous Lands (albeit some indigenous people live outside of these territories).

Peasant or *caboclo* (an Amazonian term for people of mixed Indigenous Brazilian and European ancestry) populations have adapted and established unique, complex relationships with the forest while negotiating broader social and economic change (Schmink, 2003). Understanding the Amazon's biocultural diversity, therefore, requires recognising it as a product of both natural and cultural histories, both Indigenous and beyond (Maffi, 2018). With this in mind, Amazonia can be thought of as a living landscape, where human stewardship and ecological stability are inseparable (Schaan, 2010). Yet, this vast biocultural diversity is increasingly threatened by a broad range of external stressors, most notably deforestation.

Deforestation is a particularly destructive form of land-use and land cover change (LULCC) that drives biodiversity loss, climatic variability and the loss of key ecosystem functions that support human civilisations and key planetary processes (Garrett et al., 2024). In the Brazilian Amazon, deforestation is fundamentally associated with frontier expansion, where different actors' competing visions of the future and favoured land-use strategies collide, resulting in often violent confrontations (Hecht and Cockburn, 1989; Schmink and Wood, 1992). Frontier expansion has had devastating and profound consequences for Indigenous and peasant communities alike, with many groups fighting for legal territorial recognition to stop further infringements upon their rights and livelihoods (De Souza Martins, 2002; Adams *et al.*, 2009). Amazonian frontier expansion is primarily driven by agriculture, namely extensive cattle ranching (Garrett et al., 2018). Large-scale ranching, soy production for livestock feed, and infrastructure development have accelerated forest loss across Amazonia (Schmink, 2019), undermining the biocultural systems that have sustained the region (Costa *et al.*, 2024). As these pressures intensify, the Amazon's role as both global climate regulator and biocultural homeland to diverse people is increasingly jeopardised.

Despite the deep and complex entanglement of biophysical systems and cultural systems in the Amazon, current research and practice for forest conservation has tended to neglect the importance of culture at the bioregional scale. Indeed, the future of 'hyper-diverse' forests "will require building on the cultural dimensions of research practice" (Barlow *et al.*, 2018, p. 523), which has increasingly sought to make ecological science and conservation more relevant and connected to broader society. Yet, studies of LULCC, particularly deforestation, have primarily focused on economic and political frameworks (Hoelle, 2018; Hodel, le Polain de Waroux and Garrett, 2024) that converge to dictate external market pressures, such as demand for beef domestically and globally (Gibbs *et al.*, 2016; Carrero *et al.*, 2022) Much tropical conservation, meanwhile, has focused on site-level interventions aimed at alleviating local economic poverty to protect biodiversity, often without addressing the broader, 'distant' drivers of ecological disturbance (Carmenta, Barlow, *et al.*, 2023). While these approaches (such as payments for ecosystem services) hold potential (Chan *et al.*, 2017), they often lack the social and cultural grounding necessary to produce transformative outcomes (Börner *et al.*, 2017). Consequently, prominent forest conservation initiatives in recent years,

such as *REDD+*, have often failed to achieve lasting impacts (Pokorny, Scholz and de Jong, 2013). Addressing these challenges requires an in-depth understanding of the diverse cultural contexts in which the most significant LULCC occurs.

Comparatively, the social drivers of LULCC, such as human culture, have been understudied, and their impact on large-scale change remains ambiguous (le Polain de Waroux *et al.*, 2021). Despite this neglect, research elsewhere demonstrates how landscapes evolve with culture over time (Acevedo *et al.*, 2008; Wu, 2010; Tiki, Oba and Tvedt, 2011). This myopic economistic focus on LULCC research is hard to justify in the Brazilian Amazon, which is widely recognized as a '*cultural landscape'* that has been shaped by traditional management practices long before colonial expansion (Posey *et al.*, 1984; Heckenberger *et al.*, 2007; Bush *et al.*, 2015; Levis *et al.*, 2018). Interestingly, the importance of integrating culture into LULCC research is largely neglected in studies of the drivers environmental change (Lawrence *et al.*, 2019). Adopting the definition of culture proposed by Geertz (1973) as a symbolic system, or 'web of meaning' that is shared and passed down by and among groups, and used to guide behaviours (discussed further below), it is evident that culture shapes destructive land-use decisions, such as deforestation (Hoelle, 2018).

Conservation science and practice are increasingly recognising the breadth and multiplicity of values towards nature and their importance for conservation goals, actions and outcomes (Carmenta, Zaehringer, *et al.*, 2023; Gould, Jimenez Naranjo and Balvanera, 2025; Himes *et al.*, 2025). Approaches to conservation have historically privileged a narrow set of values, generally prioritizing either the intrinsic worth of nature or the utilitarian contributions of nature to people (e.g. ecosystem services) (Raymond *et al.*, 2023). Recent contributions, however, have taken a so-called relational turn (West *et al.*, 2020; Maller, 2021), emphasising reciprocal relationships between humans and nature, and exploring how these relationships might be leveraged to support sustainable outcomes for people and the planet (Chan *et al.*, 2020, 2025; Himes *et al.*, 2024). This field of study on "relational values" (Himes and Muraca, 2018) has burgeoned in recent years. Yet much of this literature draws on environmental psychology and empirical foundations tested primarily in W.E.I.R.D (Western, Educated, Industrialised, Rich and Democratic) contexts (Gould, Jimenez Naranjo and Balvanera, 2025). Although relational values research often draws inspiration from indigenous cosmologies and understandings of 'value' (Anderson *et al.*, 2022; Himes *et*

al., 2025), how these concepts manifest in practice or interact with environmental change, particularly in Global South contexts, remains poorly understood.

Culture and relational values are receiving more attention as important influences on land-use and environmental outcomes (Hodel, le Polain de Waroux and Garrett, 2024). For culture, however, empirical evidence remains the 'missing piece' in efforts to consistently incorporate it into studies of LULCC (Caldas *et al.*, 2015). Although it is increasingly conceptually acknowledged, cultural dynamics are rarely measured in ways that allow them to be linked systematically to deforestation trajectories (Hoelle, 2018). For relational values, the challenge is somewhat different: although locally rich and meaningful, existing studies remain highly context-specific (Kleespies and Dierkes, 2020), making it difficult to draw generalisable conclusions about how values shape, or respond to, environmental change.

Moreover, relational values have largely been studied as positive, desirable connections between people and nature. However, ethnographic studies have shown that relational values can also develop for landscapes and species often considered unsustainable, such as pasture and cattle (Hoelle, Gould and Tauro, 2022). Our understanding of the diverse array of relational values (Pascual *et al.*, 2023) requires empirical testing to evaluate their composition, strength and association with environmental features across varied landscapes. Taken together, these gaps highlight the need for approaches that can systematically capture both cultural expression and relational values, particularly in frontier landscapes such as the Brazilian Amazon, where social and ecological change are deeply interlinked (Schmink, 2019; Hecht *et al.*, 2024).

Looking forward to the remainder of the general introduction, I first situate the present research within the historical and socio-ecological context of the Brazilian Amazon, in order to begin addressing the research gaps outlined above. Therefore, the next sections (**1.2.1, 1.2.2, 1.2.3**) focus on the history of deforestation across Amazonia, the role that cattle ranching played in this history, and finally, the role of cattle in daily Amazonian life, highlighting the complex and interwoven nature of cattle and frontier dynamics across the Amazon. I then outline the key literature and concepts that underpin the theoretical basis of this work, before highlighting which critical knowledge gaps the thesis seeks to address and the approaches I have taken. This general introduction then

concludes with an overview of the thesis structure and brief reflections on my research journey, including how it has shaped the direction of the PhD.

1.2 Case Study: Brazilian Amazon

1.2.1 History of deforestation across the Brazilian Amazon

Amazonian deforestation rates fluctuate over time and space due to the complex interplay of political, economic, and technological factors (Moffette, Skidmore and Gibbs, 2021). Large-scale deforestation in the Brazilian Amazon accelerated in the 1970s following military-led development programs that promoted the occupation of so-called "empty lands" across the frontier (Hecht and Cockburn, 1989), which was part of a national security strategy and a means to integrate the Amazon into Brazil's economy (Garnelo, Fearnside and Ferrante, 2023). This culminated in federal policies such as the National Integration program (PIN, 1970), and heavy investment in roadbuilding, most famously the Trans-Amazon Highway, that supported the physical, and institutional and urban infrastructure for large-scale colonization, deforestation and agricultural expansion land clearance (Viana *et al.*, 2016). Credit subsidies and fiscal incentives encouraged landowners and large corporations to convert forests into pasture, while cattle became central to securing land claims, given their relatively low sunk costs and their role in more productive use of landscapes, which was required for tenure recognition (Fearnside, 2005). By the early 1980s, cattle ranching had emerged as the dominant driver of Amazonian deforestation (Hecht, 1993). This continued through the 1990s, accompanied by increased state incentives for smaller-scale producers from other parts of Brazil, such as colonist communities, or *colonos*, in many frontier areas of the Amazon (Schmink *et al.*, 2019).

In the early 2000s, deforestation rates were extremely high, peaking in 2004-2005, driven primarily by the rapid expansion of cattle ranching and soy cultivation (Garrett *et al.*, 2018). The subsequent introduction of federal initiatives, such as the PPCDAm (*Action Plan for the Prevention and Control of Deforestation in the Amazon*) and the use of satellite monitoring systems like DETER and PRODES, contributed to a decline in deforestation rates by 2012, demonstrating the efficacy of coordinated policy and technological enforcement.

However, deforestation rates oscillated in the 2010s, reflecting how federal governance and presidential priorities are significant influencers of LULCC in Brazil (Rodrigues-Filho *et al.*, 2015; Morpurgo *et al.*, 2023). Under President Luis 'Lula' Inacio da Silva (2003 -2010), strengthened environmental enforcement, and created protected areas to reduce forest loss (Rodrigues, 2023). Lula's successor, Dilma Rousseff, had mixed results due to economic pressures and weakening enforcement. Environmental protections took a major downward turn following the appointment of Jair Bolsonaro (2019-2022) as president, who oversaw reduced monitoring capacity and encouraged land development, famously proclaiming, "The Amazon is Ours" (Phillips, 2019), all of which resulted in very high annual deforestation (above 11,000km ^{2}) in by the start of the 2020s (de Area Leão Pereira *et al.*, 2020). The current administration (Lula's third Presidential term) has signalled renewed enforcement, but historical pressures and the increased facilitated demand for land across Amazonia continue to drive deforestation (Fearnside and Filho, 2025).

Cattle ranching has played a central role in this demand for land, growing in tandem with global and domestic demands for beef (Pacheco and Poccard-Chapuis, 2012; Haddad *et al.*, 2024). Surges in international soy and beef demand have continually incentivised agricultural frontier expansion, while rural credit policies, infrastructure projects, and domestic economic growth have opened new possibilities for land clearing (Nepstad *et al.*, 2014). Although some legal and technological innovations, such as the 2012 Forest Code, the creation of Indigenous Lands, and advanced satellite-based monitoring, have helped to curb deforestation rates in some regions, market pressures, enforcement gaps, and some regional heterogeneity maintain a contested deforestation frontier across the biome (Garrett *et al.*, 2018; Carrero *et al.*, 2022).

1.2.2 Cattle ranching

Cattle ranching expanded rapidly through the 1980s and 1990s, driven initially by domestic demand for beef and leather (Veiga *et al.*, 2002). The internal market for beef was vast, and Amazonian pasture, which was cheap compared to land prices in South and South-eastern Brazil, provided a means to supply it (Siegmund-Schultze *et al.*, 2007; De Assis Costa *et al.*, 2023). Ranching was further incentivised by the hyper-inflation of the time, and cattle herds functioned as 'cash-in-hand' in a volatile economy

(Wood and Schmink, 1993). Concomitantly, global demand for beef and leather products started to exert a growing influence on the Brazilian market, especially as Brazil's beef industry modernized (Walker, Patel and Kalif, 2013). Further, the period also saw the consolidation of large ranches alongside widespread smallholder colonization projects, both of which facilitated the continued clearing of primary forest in the Amazon (Schmink *et al.*, 2019). By the late 1990s, Brazil had become a leading beef exporter, and cattle ranching was firmly established as the central driver of Amazonian deforestation (Kaimowitzavid *et al.*, 2004).

Brazil's integration into international commodity markets in the early 2000s marked a watershed moment, where the links between cattle, global demand, and forest loss became intensified (Pacheco and Poccard-Chapuis, 2012). The rise in both beef exports and the expansion of soy production led to a surge in deforestation, which peaked at 27,772 km² in 2004 (Nepstad, Stickler and Almeida, 2006). The federal government reactively launched the PPCDAm in 2004, which combined satellite-based monitoring with harsher enforcement actions, and the creation of protected areas (Azevedo *et al.*, 2017). Further, when coupled with private sector agreements such as the Soy Moratorium in 2006, and the Cattle Agreements in 2009, these interventions contributed to a substantial reduction in deforestation in excess of 70% by 2012 (Gibbs *et al.*, 2015; Pereira *et al.*, 2020). Crucially, these interventions targeted cattle directly by restricting access to finance and markets for ranchers associated with illegal deforestation, signalling the growing recognition of the sector's centrality in Amazonian LULCC (le Polain de Waroux *et al.*, 2019).

Despite these interventions, the underlying drivers of cattle-driven deforestation have persisted. The global demand for beef, especially from China since the mid-2000s, cemented Brazil's role as the world's largest producer of beef, while domestic consumption also remained high (Fearnside, Figueiredo and Bonjour, 2013; Carreira, Costa and Pessoa, 2024). Subsequent oscillations in cattle-driven deforestation were driven by the various federal forest conservation interventions and enforcements outlined above (Vale *et al.*, 2019), before cattle ranching again became a major vector of forest loss, fuelled by weakened enforcement, increasing federal support for mechanized rural Agri-production, and commodity booms during Bolsonaro's presidency (2019–2022) (Morpurgo *et al.*, 2023). In this period, cattle ranching

accounted for over 70% of deforested land use in the Brazilian Amazon (de Area Leão Pereira *et al.*, 2020).

1.2.3 The role of cattle in daily Amazonian life

Cattle ranching is the leading driver of deforestation in the Brazilian Amazon (Filho *et al.*, 2021), but the introduction of cattle to the biome is hardly recent. Cattle raising in the Amazonian floodplain dates back centuries (Sheikh, Merry and McGrath, 2006). Cattle play a noteworthy role in major (mass participation) folkloric festivals across Amazonia, such as *Boi-Bumbá* in Manaus and Parintins, Amazonas State, which tells the story of a humble labourer (typically of African descent, or *caboclo*) that kills the prized bull of a wealthy cattle rancher (typically of European descent) to feed its' tongue to his pregnant wife and flees into the forest, before being caught and forced to bring the cow back from the dead (Watson, 2018). Such imaginaries are central to the cultural identity of many Amazonians, holding deep cultural value, regardless of socio-economic standing (Watson, 2015).

Cattle are not only seen as a viable and sometimes necessary method of livelihood security; they also represent the dream of many rural Amazonians, even on a small scale (Hoelle, 2011). Although cattle have often been framed as a natural antagonist to traditional forest livelihoods and extractivism (Salisbury and Schmink, 2007), they are not simply substitutes for one another. Gomes et al. (2012) demonstrate that despite historical tensions between forest-extractivist peasant communities and large-scale cattle ranchers – as a consequence of the violent history of land-dispossession (or *grilagem)* between these groups across Amazonia – traditional peasant communities are beginning to invest in small-scale cattle ranching. The benefits of cattle (in any quantity) are varied and numerous: Small herds can provide a form of tangible savings, insurance, and often encourage social recognition that forest products rarely offer in contemporary markets (Salisbury and Schmink, 2007). Moreover, cattle embody an asset that is mobile, divisible, and relatively liquid, allowing households to manage risk and pay for essential aspects of their livelihoods, like education and health crises (Siegmund-Schultze *et al.*, 2007). Importantly, this form of material security has rarely been possible for many Amazonians who rely on traditional forest produce (such as harvesting Brazil nuts and tapping rubber) to make ends meet (Adams *et al.*, 2009). In

this sense, cattle have supplemented the livelihoods of people who would likely identify themselves as traditional peasant communities, which has enabled families to diversify not only forms of income, but cultural traditions that were originally singularly rooted in forest-dependence, while also accessing increased material security and cultural prestige associated with livestock ownership (Hoelle, 2011; Adams, 2015).

For many traditional farming families engaged in *agricultura familiar*, cattle are also increasingly central to cultural identity and social reproduction. Owning cattle can mark a household's transition from the social status of *trabalhador* (a worker reliant on daily labour or forest extractivism) to being recognised as *proprietário* (a landholder with productive assets) (Hoelle, 2011). This symbolic aspect of cattle reinforces their importance beyond economic security, and instead affixes them into intergenerational aspirations of how to live a 'good life' (Hoelle, 2015; Dodd, 2020), as well as local status hierarchies and broader narratives of Amazonian development (Guanziroli, Buainain and Sabbato, 2013).

Importantly, the literature to date suggests that rather than representing mutually exclusive worlds, forest extraction (sustainable interactions with landscapes) and cattle raising (which is often framed as unsustainable) may coexist in hybrid livelihood strategies (Fraser *et al.*, 2018). This hybridity reflects broader processes of social change, the efforts of peasant communities to integrate into larger markets (Fraser *et al.*, 2018), and their negotiations of the complexities of contemporary identity in specific contexts across Amazonia (Nugent, 1997; Gomes, 2009). Indeed, as Hoelle (2015) highlights, cattle can be cultural symbols that shape how rural Amazonians imagine *progress*, *masculinity*, and *hard work* within developmental narratives. This complicates dichotomous portrayals of traditional forest vs ranching cultural identities. Rather than opposites that represent 'one or the other' dynamics, the literature presented above points to the need for deeper and more nuanced understandings of how cattle increasingly shape cultural identities for traditional communities (Gomes, Vadjunec and Perz, 2012).

Cattle are embedded in the everyday lives and social imaginaries of Amazonians, shaping social aspirations, status, and indeed, *culture*, across many rural contexts (Hoelle, 2014). Recognising the symbolic dimension of cattle as an important aspect of Amazonian development (even on smaller scales) complements the analytical focus of

this thesis: understanding culture as a lens through which we might interpret the diverse values, practices, and identities that emerge across Amazonian frontiers. This points to the need to situate the thesis aims within broader scholarship on culture and its relationship with LULCC, and more specifically *cattle*, as an important shaper of values, practices, and identities in advancing deforestation frontiers of the Brazilian Amazon.

1.3 Key concepts of this thesis

This thesis uses an interdisciplinary approach in which social science survey techniques and the use of big data are grounded in ethnographic theory on cultural identities and contemporary cultural expression across Amazonia. In attempting to quantify cultural expression and relational values at farm-forest frontiers in the Brazilian Amazon, this thesis draws on a diverse range of academic disciplines, including human geography, political ecology, cultural anthropology, ecology, ecological economics, and ethnomusicology. This thesis leverages this interdisciplinarity to examine how traditional peasant culture and cattle culture varies across the frontier, and the association between frontier advance and people's relationships with forests. As such, it relies on various concepts that, while related, are distinct and underpinned by separate disciplinary literatures.

1.3.1 Inconsistencies in defining 'Culture'

Culture is a hotly contested topic among scholars of the same discipline, let alone across disciplinary boundaries (Zagaria, 2021). Culture has been described as 'sticky', 'messy', and even "riddled with academic contention" (Patterson, 2014, p. 2). Largely, this contention is due to the sensitive nature of how culture is depicted, shared, and interpreted by different societal groups. According to Patterson (2014), we are in a current age of 'identity', in which everyone challenges one another not solely on how their culture is interpreted, but also the very definition and meaning of culture itself.

Zagaria (2021) directly addresses the gap in the definitions of culture between the natural and social sciences (anthropologists are included in social sciences in this case). Describing the natural sciences definition of culture as, broadly, a "tradition of socially

learned behaviours", which can even be observed in animals (insects included) through repeated 'social learning'. However, critics have argued that this definition "stagnates when trying to satisfactorily explain the richness and variety of human culture" (Zagaria, 2021, p. 853).

On the other hand, a 'Culturalists' account of culture would align more closely with Geertz's (1973) "Webs of Significance", where the symbolic aspect of culture, and the concepts of "sense-making" and "meaning" are common patterns shared by social scientists. Yet, this definition of culture has been debated for some time, with no "golden standard" accepted by the field of anthropology, from which cultural studies emerged (Martin, 1998). The bifurcation of definitions between the natural and social sciences has been attributed by Zagaria (2021) to a diversion in ontology (*what culture is*), and epistemology (*how we should study it*).

Culture has been fiercely debated among social anthropologists and sociologists, due to the varied nature of culture between societies, peoples, ethnic groups, and even sub-groups (Kuper, 2000), a problem that is only compounded when looking at culture from an interdisciplinary perspective. Adam Kuper's (Kuper, 2000) book, titled 'Culture', details the divergent paths that Anthropology takes from its progeny, Cultural Studies, when examining culture. As Kuper describes, anthropology views culture as more saliently imbued in the ways that we live, including our values, societal norms, and what we consider to be *good* and *right*. Importantly, this focus is narrowed in cultural studies, where culture can be observed in art, language, literature, and entertainment as ways that people express their culture.

According to an anthropological perspective, culture is present in daily habits, values, decisions, and norms (Hays, 1994). Its features are not typically captured by official categories or classifications, but generally expressed in the everyday practices of institutions that structure social and economic life (Ostrom, 1990). While largely invisible to outsiders, culture acts to guide the ways that people interact with each other and, importantly, their environment (le Polain de Waroux *et al.*, 2021). Much of culture operates in this subtle and largely invisible space, this thesis focusses on one of its most tangible aspects is what I will now term as cultural expression: how the abstract concepts of culture discussed throughout this section are manifested in daily life and social practices (Becker, Kraus and Rheinschmidt-Same, 2017).

1.3.2 Cultural expression

Cultural expression refers to the ways that people communicate identity, meaning, and values through art, music, entertainment, rituals, traditions, language, cuisine, and even architecture, among other things (Kim and Sherman, 2007). It is one of the main methods of articulating broader worldviews, heritages, and is an important aspect of placemaking for many (Beza *et al.*, 2018). Cultural expression is typically embedded in social and ecological contexts, with cultural expression through shared practices often arising in relation to place, land, and environment (Iverson Nassauer, 1995).

The methods of studying cultural expression vary widely across disciplines. Cultural anthropologists, cultural geographers, and ethnomusicologists most commonly employ ethnographic methods to tease out the deeper meanings and 'webs of significance' that cultural expression invokes (Martin, 1998; Miller, 2011). These approaches (deliberately) typically tell us an incredible amount about a singular culture or group of cultures in only one place. Ultimately, this means that making any generalisable assumptions about similarities or differences in cultures and cultural expression between people in different places remains elusive using these methods. While ethnographic work provides depth at local scales, recent computational approaches offer breadth across regions and populations. Specifically, they have sought to answer broader questions about cultural variation between places and people groups by using measurable markers of culture as a proxy for broader cultural identities, namely music, consumer choices and food preferences.

Recent advancements in the field of demography have extended the concept of cultural expression by examining cultural assimilation between neighbouring communities and by considering the role of physical distance in shaping cultural differences. Pichl *et al*. (2017) utilised Spotify listening data from ~2,700 users to model listener similarity based on geographic proximity (GPS locations). The authors outline how the modelling of musical preferences into clusters based on genre similarity can be used to determine cultural similarities (and differences) between people in different countries and even continents.

Similarly, Stewart *et al*. (2019) used Facebook market API data to understand how the musical preferences of different generations of Mexican-Americans (including Mexican

immigrants, first-generation Mexican-Americans, and second-generation English-only speaking Mexican-Americans) became more similar to different ethnic groups (including African-Americans and Caucasians) living in close proximity. This study subsequently challenged portrayals that Mexican American communities refuse to culturally assimilate to the general U.S. populous, which have contributed to development of xenophobic narratives.

Vieira *et al*. (2020) examined how Brazilians that had emigrated to other countries reproduce their national culture and identity through typically Brazilian food preferences, also using Facebook API methods. In this global study, they effectively utilise the concept of 'distance' - both geographic and cultural - to evidence how social media cultural data can be used as a proxy to understand cultural affinities between geographically distant countries.

Taken together, these studies suggest that, although fundamentally different from cultural anthropology in its aims, quantitative data offers tremendous potential to understand variation in cultural expression across distant geographies. These methodological developments open the door to probe how cultural expression interacts with processes that reshape environments, including land-use and land-cover change (LULCC).

1.3.3 The role of culture in land-use and land cover change

Culture is seldom incorporated into the statistical modelling of environmental change (Hodel, le Polain de Waroux and Garrett, 2024), even though values and cultural norms are critical to achieving sustainability (Ives and Fischer, 2017). Many deeply held identities, values and norms interact to guide behaviours and collective decisions (Kenter, 2016), meaning cultural variations can lead to significant differences in how communities respond to environmental pressures (Caldas *et al.*, 2015). Yet, culture is often acknowledged as background context rather than an active shaper of environmental outcomes, which has limited attempts to actively integrate it into the study of LULCC (Hoelle, 2018).

Group cultures can be tethered to geographic locations or landscapes (Kottak, 1999). Landscapes are imbued with culture, helping to develop new heritage, stories, and ways

of living (Wu, 2010). When cultural norms tied to historical landscapes and idealised ways of living are transplanted to new contexts, they can transform local land-use trajectories (Seweryn, 2007). This is evident in cases where migrant agriculturalists reshape forest frontiers, including when *cattle culture* is introduced following large-scale pasture expansion in the Amazon (Hoelle, 2018). Such transformations hinge on what different groups imagine as an 'ideal' landscape (Milton, 1997; Plumwood, 2006), which is sensitive to social composition changes due to migration or population ageing (Kendal and Raymond, 2019).

While the role of culture in LULCC is increasingly acknowledged, barriers persist to integrating it into land-use models and other analyses. A central challenge is empirical measurement. For instance, cultural expression (the most tangible aspect of culture) is yet to be quantified at the scale and granularity required to align with environmental change at the bioregional scale. Yet, it is precisely through cultural expression that the abstract notions of values, norms, and identities become visible in everyday practices (Kim and Sherman, 2007). This makes using tangible markers of cultural expression it a promising avenue for linking culture to land-use outcomes. Recent advancements in big data approaches to measuring cultural expression provide a unique opportunity to do exactly this.

Interestingly, ethnographic work at a farm-forest frontier in Acre (Western Amazonia) shows that expanding pasture for cattle ranching can reshape cultural expression (such as strong preferences for cowboy clothing and beef over other regional foods) and, in turn, cultural values (Hoelle, 2014, 2015). This dynamic points to the emergence of a distinct *cattle culture* in the Brazilian Amazon, where both the explosive growth of ranching and vast in-migration has accelerated the diffusion of new cultural identities across the region.

1.3.4 Cattle culture

Cattle culture is described by Hoelle (2015) as the positive cultural constructions that are associated with cattle raising, among which higher status, power, security, and wealth are desirable biproducts (Hoelle, 2018). Hoelle builds on earlier studies of the shift towards cattle in rural Amazonian landscapes, such as Salisbury and Schmink (2007), who identify rearing cattle as *high status*, and an opportunity to cut risks to the

landholder drastically over other alternatives. Interestingly, Hoelle (2011) points out that cattle raising was considered by many people in rural Amazonia to be a 'despicable' way to make a living merely a couple of decades ago; yet, as global demand beef rose (Cohn *et al.*, 2014), even social groups without historical ties to ranching, such as rubber tappers, began entering the industry (Gomes, Vadjunec and Perz, 2012).

Hoelle (2011) identifies three main drivers behind the rise of cattle culture in the Amazonian state of Acre between 1990 – 2010: (1) Political and economic shifts, that have undermined the economic stability of traditional agricultural and extractivist livelihoods, such as rubber tappers, Brazil nut harvesters, or wildmeat hunters; (2) Spread of positive cultural views associated with cattle rearing, of which wealth, status, security and prosperity are central; and (3) a shifts from violent land conflicts and dispossession toward more intergroup cooperation.

These dynamics materialise into what Hoelle (2015) conceptualises as five key themes of cattle culture (see Figure 3.2, **Chapter 3**): (1) The perception or belief that raising cattle is the best way to use the land; (2) The ascription of positive social attributes to people or groups who raise cattle; (3) the valorisation of a cattle-based lifestyle through popular fashion and activities related to cattle; (4) the frequent consumption of beef and its symbolic meanings; and (5) a preference for interacting with nature through cattle and pasture, emphasising human control over the forest and nature.

The third theme highlights the importance of cultural expression to LULCC. Hoelle (2015) notes parallels between cattle culture in Acre and *Cauboi* (Cowboy) traditions in Southern and South-Eastern Brazil, where fashion, music, rodeos, and barbecues play central roles. Among these, Brazilian country music, or *Sertanejo*, is especially influential. Its traditional roots form, *Sertaneja raiz*, has long idealised rural life and cattle ranching as a marker of prosperity and tradition (Dent, 2009; Lima, 2019). Through lyrics valorising land cultivation and often ranching lifestyles, Sertanejo reinforces cultural values where forests represent *laziness* and pasture represents *progress* (Hoelle, 2018). The genre's influence extends into fashion, colloquial language, and identity, while newer sub-genres such as *Agronejo* glamorise agri-business and rural modernity (Martins and Teixeira, 2023). As a form of cultural expression, music provides a powerful medium for the reproduction and diffusion of collective values, paralleling cases where genres like Punk and Hip-hop have reshaped

social movements and personal identities (Tillman, 1980; Bennett, 1999; Fingerhut *et al.*, 2021). Indeed, this suggests that Sertanejo goes beyond mere entertainment, forming a cultural vehicle for the spread and consolidation of cattle culture across Amazonian frontiers (Hoelle, 2015, 2018).

Through music that valorises rural lifestyles and production, perceptions of cattle as the best way to use the land, and cultural preferences for pasture over forest, cattle culture exemplifies how cultural expression can reorient values towards landscapes in ways that drive LULCC. These dynamics can be examined through the concept of *relational values*, which describes the relationships that people have with nature beyond just material use (like resources) or intrinsic worth.

1.3.5 Relational values

Relational values, or the reciprocal relationships between humans and nature (Chan *et al.*, 2016), are increasingly acknowledged as important for conservation, sustainability, and human well-being (Himes and Muraca, 2018; Carmenta, Zaehringer, *et al.*, 2023). Importantly, there are several key differences between relational values and cultural expression: Cultural expression is typically embedded in social-ecological contexts through cultural practices that arise in relation to place, land, and environment, and is expressed through mediums such as art, music and food (Kim and Sherman, 2007; Nugent, 2009). Relational values can be understood as a part of culture that emphasizes the connection and responsibility that people feel towards and for nature, and are formed with individual landscape features or species, like trees (Uehara, Sakurai and Tsuge, 2020). They indeed have much in common, such as being rooted in relationships, and are tied to identity and belonging (Ishihara, 2018). Perhaps most importantly, both culture more broadly (see Spaargaren, 2011; Caldas *et al.*, 2015; le Polain de Waroux *et al.*, 2021; Hodel, le Polain de Waroux and Garrett, 2024), and relational values as part of culture (see Himes and Muraca, 2018; Chan *et al.*, 2020; Jacobs *et al.*, 2020; West *et al.*, 2020; Arias-Arévalo *et al.*, 2023; Raymond *et al.*, 2023) have been theorised to hold tremendous potential for sustainable environmental decisions and transformations.

However, the relational values literature also lacks sufficient empirical evidence that could help to facilitate neater integration with global conservation efforts. While relational values have become a central feature of the so-called ‘relational turn’ that

conservation science is now taking (West *et al.*, 2020), much of the forest conservation discourse is still dominated by perspectives from environmental economics, which highlights how ecosystems support planetary and public health (du Bray *et al.*, 2019). Similar to a lack of empirical studies examining cultural expression across Amazonia, limited empirical research has explored the composition of relational values (Kleespies and Dierkes, 2020), and fewer still across a diverse range of environmental and social contexts (Schulz and Martin-Ortega, 2018) among marginalized populations, such as the Brazilian Amazon. This is problematic because much of the initial psychological research informing the foundations of relational values concepts was conducted in W.E.I.R.D (Western, Educated, Industrialised, Rich, and Democratic) contexts (Gould, Jimenez Naranjo and Balvanera, 2025), even as more recent developments driven by international policy reports (see IPBES, 2022), have attempted to ground relational values in Indigenous and traditional ontologies (Gould, Martinez and Hoelting, 2023; Himes *et al.*, 2025; Virtanen *et al.*, 2025).

Moreover, there are gaps in our understanding of how relational values are formed with species or landscape features commonly understood to be unsustainable or altered by landscape change. Hoelle et al. (2022) outlines how the growing importance of cattle in Acre has led to reciprocal relationships between people and cattle, something the relational values literature does not currently explicitly acknowledge. Further, Mikołajczak et al. (2021) found no evidence that a lack of access to nature for rural farmers living and working along the Trans-Amazon Highway was related to how connected they felt to forests, which was more dictated by social factors. Interestingly, a study based on four international case studies concludes that landscape simplification (e.g. forest clearance for pasture) leads to the erosion of values for natural landscapes (Riechers *et al.*, 2020).

The need to understand how these reciprocal connections with and values for nature are impacted by environmental outcomes is clear, which requires empirical evidence across varied social-ecological contexts. Yet, it is evident that these values must also be situated within broader social and political processes. In the Brazilian Amazon, traditional peasant cultures, cattle culture, and relational values, are deeply entwined with agricultural deforestation frontiers (Hecht, 2010). Historical processes of violent land dispossession, migration, and competition among diverse actors have shaped landscapes and social composition (Schmink, 1982; Hecht and Cockburn, 1989; Little,

2001). Situating cultural expression and relational values within these frontier dynamics provides a critical lens for understanding how identities, values, and environmental relationships are formed, contested, and transformed across phases of landscape change.

1.3.6 Frontiers in the Brazilian Amazon

Rapid and violent LULCC in the Brazilian Amazon can be understood through the concept of frontiers (Thaler, 2017). Drawing on political ecology, frontiers are not only biophysical processes of deforestation and biodiversity loss (Goebel *et al.*, 2025), but violent social processes marked by displacement, contestation, and the expansion of the agricultural industry (Hecht and Cockburn, 1989; Carrero *et al.*, 2020). They encompass demographic, cultural, political, social, and economic shifts that reconfigure both landscapes and livelihoods (Little, 2001). Although deforestation frontiers may bring temporary material gains — such as improvements in key poverty indicators — these are often fleeting, characterised by 'boom-bust' development cycles (Rodrigues *et al.*, 2009; Alencar, Parry and Melo, 2025).

Frontiers differ in intensity and composition, as diverse actors converge, often violently, to contest land-use strategies (Schmink and Wood, 1992). Schmink et al. (2019) stress that frontiers are the result of sedimented socio-ecological processes, and are somewhat disconnected from linear narratives of national development and the overarching capitalist structure (Thaler, Viana and Toni, 2019). They are not only arenas of resource extraction but also ideological battlegrounds, where competing visions of ideal landscapes and futures clash (Hecht and Cockburn, 1989; Little, 2001). Frontier trajectories, then, are determined by the victors of these contests (Thaler, 2024), where developmentalist governance and pro-agricultural institutions often stand in stark contrast to Indigenous and traditional cosmologies of forest stewardship (Nugent, 2010; Kröger, 2020; Parry *et al.*, 2025).

Scholars have conceptualised frontiers in 'stages' or 'phases' (see Rodrigues *et al.*, 2009; Alencar, Parry and Melo, 2025), linking frontier progression to forest loss and livelihood change in Brazil. While useful, this framing can risk oversimplifying the complex socio-ecological dynamics at play (Arima *et al.*, 2016; Thaler, Viana and Toni, 2019). Building on these approaches, this thesis employs frontier stage classifications as a heuristic but extends them by situating deforestation within ethnographic

understandings of cultural expression and relational values. By examining municipalities where agricultural expansion (particularly through cattle ranching in later frontier 'stages') has reshaped forests to varying degrees, we might explore how frontier dynamics can reconfigure cultural expression and relational values and infer how these in turn may shape LULCC.

1.3.7 Space-for-Time Approaches

Space-for-time (SFT) substitution is a widely employed method to deduce past or future changes in biophysical systems using spatial patterns (Blois *et al.*, 2013). In ecology, this method is typically used as a substitute for when longitudinal (or time-series) data for a particular interaction, behaviour, or effect is unavailable or impractical to collect at the time of the study (Johnson and Miyanishi, 2008). SFT thus allows scientists to predict future changes to important ecosystem functioning or climate changes that impact social systems (Thomaz *et al.*, 2012). SFT methods are particularly useful in times of rapid and uncertain climatic changes (Angert, 2024), such as during the mid-2020s when this thesis was written, and has at times been used to inform policy recommendations offered by ecologists and climate scientists (Lovell *et al.*, 2023). As such, SFT has been characterised as a convenient and often cost-effective substitute in the absence of reliable long-term datasets.

However, it is important to note that SFT approaches have received criticism in recent years. Angert (2024) suggests that instead of a direct substitute, SFT should be leveraged with sparse time-series data because of the risk for inconsistent test conditions between spatial plots that would otherwise be replicable in a longitudinal study. Moreover, Liu ad Wu (2025) found that when comparing results using SFT and time-series methods in tandem in the same study area, while some results are similar, a number of results differed substantially. This could underpin the notion that instead of being a direct substitute for one another, these approaches should be complimentary or seen as approaches that yield different outcomes, each of which may be useful for informing future forecasting and policy. The comparison of different data types as direct substitutes may lead to future forecasting uncertainty (Evans *et al.*, 2025), and as such, while SFT is a useful tool in the absence of time-series data, results yielded from this method should be interpreted with caution (Damgaard, 2019), especially if a study combines the modelling of ecological and human social phenomena, adding another layer of complexity, as this thesis does.

1.4 Key knowledge gaps

Despite advances in the study of how culture interacts with LULCC, and novel methods to measure culture empirically, key knowledge gaps remain. This thesis aims to understand how culture changes over space (using a space-for-time substitution approach), how cultures can be displaced and replaced across space, and how to measure culture empirically for integration with LULCC data.

It remains unclear how culture interacts with environmental change across diverse and unique social-ecological contexts. While there is extensive evidence of local-scale changes to cultural practices in response to land-use change, convincing methods for systematically integrating culture with spatial analysis of LULCC remain sparse (le Polain de Waroux *et al.*, 2021; Hodel, le Polain de Waroux and Garrett, 2024).

Ethnographic work has provided valuable insights. For instance, Hoelle (2011, 2014, 2015) documents how the arrival of cattle to the Brazilian Amazon is associated with the diffusion of '*cattle culture'*, a set of positive cultural constructions linked to prosperity, wealth, and modernity. Such dynamics may reduce people's sense of connection to forests (Hoelle, Gould and Tauro, 2022), or to foster values that prioritize pasture over forested landscapes (Hoelle, 2018). However, these findings are largely confined to the Western Brazilian Amazon (Acre State), making it difficult to know whether similar cultural transformations occur in other frontier contexts. While related studies elsewhere (Gomes, 2009; Assunção *et al.*, 2017; Gomes *et al.*, 2018) have explored changing livelihood strategies among small-scale farmers and forest extractivist communities, they have not directly examined how these shifts reshape cultural identities or influence longer-term land-use decisions.

Moreover, local-scale research has evidenced that the transition from forest-dependency to cattle and its' relationship with identity and culture is not necessarily linear (Gomes, Vadjunec and Perz, 2012). Although cattle-raising has often been framed as a natural antagonist to forest-based cultures and identities (Schmink, 2003; Salisbury and Schmink, 2007; Nugent, 2017), existing research has not yet clarified when and how cattle culture displaces, coexists with, or reshapes forest-oriented culture and thus, values.

Finally, despite broad agreement that culture should be integrated into the study of LULCC, there is still little consensus on how culture can or should be measured in empirical terms. This gap represents both a theoretical challenge and opportunity for methodological innovation, with new developments in demography providing a useful blueprint (e.g. Stewart *et al.*, 2019). A parallel issue arises from the relational values literature: although widely recognised as central to understanding human-nature relationships, most empirical work has been conducted in W.E.I.R.D. contexts (Chan *et al.*, 2025; Gould, Jimenez Naranjo and Balvanera, 2025), with limited testing in Amazonian frontiers or other rapidly changing landscapes. Developing novel ways to quantify both cultural expression and relational values in such contexts is therefore crucial for understanding how environmental and cultural transformations unfold together.

1.5 Aims and Contributions of the Thesis

The aim of this thesis is to understand the relationship between advancing deforestation frontiers of the Brazilian Amazon and culture. Specifically, it addresses the lack of empirical methods for integrating culture into the study of LULCC. Building on ethnographic work by Jeffery Hoelle (Hoelle, 2011, 2014, 2015, 2018), this thesis advances understanding of how cattle-driven agricultural expansion is associated with cultural expression related to both traditional Amazonian identities and cattle culture. In doing so, it also outlines the composition of relational values at Amazonian frontiers, exploring how they can be empirically assessed in rapidly changing frontier settings, moving beyond W.E.I.R.D. contexts. Thus, this thesis explores the following research questions:

1) How do musical preferences and other forms of cultural expression change across deforestation frontiers? (**Chapters 2, 3**)
2) How are environmental relational values associated with deforestation and landscape change? (**Chapter 4**)
3) Do variations in cultural expression and environmental relational values across a deforestation gradient differ between urban and rural populations? (**Chapters 3, 4**)

4) To what extent is cultural change at frontiers associated with migration? (**Chapters 2, 3**)
5) Can people's meaningful relationships with one another and their environments be quantified? (**Chapters 3, 4**)

1.5.1 Thesis Structure Outline

Chapter 2 aims to provide the first large-scale quantitative assessment of how variation in cultural expression (using musical preferences as a proxy) relates to forest loss, pasture expansion, and cattle ranching across Amazonia. By linking local radio-playtime data of various genres with land-use demographic and deforestation indicators, manifestations of 'cattle culture' are shown spatially across the deforestation frontier. The key methods of this chapter include:

- Cross-sectional 'space-for-time' design across 375 municipalities
- Municipality-level musical profiling, following classifications of genres for 3,427 songs (~9 songs per municipality) from 1,069 radio stations (6-month sample, 2023)
- Integration of musical genre classifications with secondary data on cattle herds, deforestation and demographic data, focusing on Sertanejo as main genre of interest for cattle culture expression
- Statistical modelling controlling for migration and road connectivity

Chapter 3 aims to compare cultural markers associated with traditional Amazonian identities and cattle culture at distinct deforestation frontiers across Amazonia, and to understand how these markers may differ or shift depending on socio-ecological context. Using a cross-frontier design, this chapter identifies how frontier stage, rural-urban primary residence, and migration history shape the expression of these culture markers, using the following methods:

- Structure surveys (n = 407) across rural and urban populations in four Amazonian municipalities
- Construction of cultural identity factors reflecting traditional Amazonian forest peasant culture and cattle culture

- Statistical comparisons and modelling of cultural markers for these factors across frontier stages, rural-urban context, and migration histories

Finally, **Chapter 4** aims to systematically compare the population-level composition of relational values across Amazonian deforestation frontiers, interrogating how average values respond to forest loss and cattle-pasture conversion of both urban and rural people across Amazonia. This chapter identifies how frontier stage, rural-urban residence, and surrounding landscapes of rural residents relate to the composition of relational values towards forests and cattle or pasture. The key methods used were:

- Structure surveys (n = 407) across rural and urban populations in four Amazonian municipalities (i.e. the same survey as Chapter 2)
- Data-led identification of four categories of relational values based on confirmatory factor analysis: Forest identity & importance, forest utility, cattle identity & importance, and cattle utility
- Statistical comparisons and modelling of relational values factor scores per survey respondent

1.5.2 Research Journey and Reflections

The aims and scope of this thesis have remained relatively stable, though my research path shifted in some important ways. At the outset, I planned to develop a cultural index that could quantify multiple aspects of popular culture and use it as a predictor for environmental change. My initial strategy was to draw on large-scale API data from social media platforms, following methods used in demographic research (Pichl *et al.*, 2017; Stewart *et al.*, 2019; Vieira *et al.*, 2020). However, regulatory changes in 2021 banned this form of data collection. After testing alternative approaches — including manual searches for data on Amazonian music festivals — I eventually developed the radio-based data collection method used in **Chapter 2**, a process that took seven months. Someone starting this PhD now may instead outsource this job to artificial intelligence (AI) for much quicker returns, which saw rapid improvements from 2024 onwards.

Alongside this methodological redirection, a major component of the project became remote fieldwork in the Brazilian Amazon. After beginning to study Brazilian

Portuguese in 2022, I conducted a brief pilot study in Belém, Pará state. I returned in 2024 for 10 months, where I was a visiting doctoral researcher at the Amazonian Institute of Family Agriculture, Federal University of Pará in Belém. Guided in-part by my interactions with research staff and students and inputs from my project supervisors and collaborators, I designed an original survey tool that assessed cultural expression (**Chapter 3**) and relational values (**Chapter 4**). This marked my first experience collecting primary data in the field and conducting survey research. Over a four-and-a-half-month rural field season starting in Lábrea (Amazonas State) and finishing in São Félix do Xingu (Pará), I carried out more than 400 surveys across four municipalities, assisted by field assistants I recruited in each place, *Paula, Gustavo, Ray,* and *Paulo*. These municipalities are thousands of kilometres apart and were reached by a combination of planes, buses, and boats. I relied on previous networks established by project supervisors (Luke, Valério) to establish initial connections in each municipality and had help from *Dr.. Juliana Silveira*, a postdoctoral researcher at Lancaster University who was working in Paragominas at the same time I arrived there. However, most of this fieldwork was conducted alone and demanded navigating significant logistical, inter-cultural, and personal challenges, which also generated the foundation for the analyses presented in later chapters.

Ultimately, these experiences reshaped the project from its initial emphasis on large-scale digital traces of culture toward more grounded, field-based survey research. This allowed me to engage more directly with cultural practices and values in diverse contexts of Amazonia, ultimately strengthening the thesis' contribution to understanding cultural expression and relational values across deforestation frontiers in the Brazilian Amazon.

1.5.3 Researcher Positionality

A critical component of any research project is the positionality of the researcher, and how that shapes the epistemological direction of the research, core research questions asked, key knowledge recognized, methods used, and ultimately, the project findings. This thesis is no different and has been undoubtedly shaped by my own academic trajectory, identity, and privileges as a European-born, English speaking, male, mixed

ethnicity researcher studying people's relationships with one another and their environment in Latin America at a rich and well-respected English university.

First and foremost, my previous academic training in Accounting and Finance (BS.c.), and then Environmental Economics (MS.c.) steered me towards a Postpositivist research epistemology, in that I assert that true objective knowledge is likely impossible to achieve (Zammito, 2004), yet I have striven for a justifiable understanding of human-nature relationships through quantitative methods. To address some of the limitations of this epistemological approach, I sought out collaborations with academics that examine and understand these relationships in different ways to my own during the course of my doctoral studies, such as an American Anthropologist (Dr. Jeff Hoelle at the University of California, Santa Barbara, USA) and a Brazilian Human Geographer (Prof. Dr. Carlos Valério Aguiar Gomes at the Federal University of Pará, Brazil), who became not only collaborators but my co-supervisors. This helped to keep this thesis grounded in the cultural realities of my field of study and was aided by my integration as a visiting researcher in both the USA (3 months in 2023) and Brazil (2 months in 2022, 10 months in 2024).

Prior to undertaking this doctoral study, I had no connections to Amazonia. This project represented a new research journey for me, and one which I undertook out of both interest in the research topic and the global importance of the Amazon rainforest. However, as a European-born researcher of mixed Jamaican and European heritage, there are some important caveats to note. Primarily, even as a complete outsider, I was welcomed into Brazilian institutions, organisations, and homes. While this is undoubtedly an artefact of the generosity of the many researchers, professionals and research participants that aided this study's completion, these interactions must be situated in the legacies of European colonialism and conquest of South and Central America (Fanon, 1963), and the deep ramifications this has for social interactions between Europeans and Brazilians centred around power, or the lack-thereof of Brazilian people relative to Europeans historically (Hordge-Freeman, 2015). This, taken with my similar features and skin-tone to many people that I interviewed due to my West-African and European ancestry, afforded me many privileged interactions during fieldwork, where data for 2 of the 3 chapters (**Chapters 3** and **4**) presented in this thesis was collected.

This has important ethical considerations for this research, ones that I have endeavoured to address through my studies. Firstly, conservation research conducted in the Global South by researchers from and particularly working in the Global North risks engaging in 'parachute science' (de Vos and Schwartz, 2022), where research is conducted with no tangible benefit to the people that participate, nor to the local researchers and organisations that make the research possible. I have attempted to combat this by working with Brazilian researchers, recruiting and training research assistants (whom I continue to provide guidance and help for their research careers), offering authorship credit in-line with up-to-date guidance, and being transparent about the research aims and objectives with research participants, while always obtaining permission from a community representative before conducting surveys during fieldwork (de Vos, 2022; Odeny and Bosurgi, 2022) and seeking appropriate research permissions, either through my own ethics applications or through wider project ethics approvals obtained by my primary supervisor prior to fieldwork. Moreover, I have plans to communicate the findings of this research to local collaborators and my academic collaborators digitally following formal examination, and hope to secure research funding to return to multiple communities that participated in this research project to disseminate my findings and to try and understand how my research (or similar) could be more useful to them in future (Johnson *et al.*, 2022). Some ideas for disseminating this research and successfully integrating local voices in my future research could be to hold *roda de conversas* (conversation circles that typically allow for equal interactions between people and open-minded discourse), or participatory mapping with community members where they outline local areas of most importance for them for future research priorities (Tosi Roquette and McCall, 2021). Yet, much work remains to be done to combat the historical imbalances in knowledge extraction, ownership, and recognition that Global North researchers have proliferated since the onset of colonial exploration (Vanner, 2015).

Finally, this research, and my interactions with Brazilian and South American researchers was also shaped by my own identity as a Black, British Jamaican, first generation university-goer/researcher that attended a poorly performing state school in a neighbourhood in the lowest 1% of progression to higher education in the U.K. This reality has inevitably influenced my own ways of navigating and participating in European scientific traditionalism and extractive practices (Vanner, 2015). These

defining traits of my identity meant that perhaps this research took on non-traditional dimensions, such as seeking out local expertise and guidance, or taking influence from decolonial scholarship may not have been as thoroughly considered. Furthermore, my identity as a non-white British person in Brazil meant that I often escaped negative interactions that might have otherwise been experienced by a White British researcher conducting research in the tropics. Furthermore, my strong ties to Jamaican culture (which is similar in many ways to Amazonian Brazilian cultures), and my visible Jamaican ancestry, such as through my hair being styled in dreadlocks or brown skin, meant that many initial barriers that might have been faced to conducting this research with marginalized communities were circumvented, a privilege that is worth noting. Importantly, much of my reflective thinking was also encouraged by my supervisors, especially Luke Parry, who always reminded me to engage directly with my North American heritage and the important decolonial literature published about the nature of scientific exploration and discovery in the Global South prior to conducting fieldwork. With all these considerations in mind, an important point remains to be made about the potential direction this thesis could have taken, had this research been undertaken by someone from a different academic background, country, continent, gender, or race. This research may have benefitted a qualitative focus across different contexts, yet I strove to understand trends using quantitative data because of the rich place-based ethnographic work done by two of my supervisors on related topics. Another researcher may have applied contemporary feminist or queer ecologies perspectives to understand how the marginalisation of women and LGBTQ+ communities and identities across Amazonia converges with the points I go on to make, which is an important yet distinct issue (Hecht, 2007; Hodel, 2023). Moreover, future research would benefit substantially from auto-ethnographic perspectives by Amazonian people (such as *caboclos*) living with the realities of agricultural frontier expansion, something that I am not aware of having been published to date in an academic format. A key benefit of this would be that it would serve to amplify the voices of those living through the things that I researched throughout this thesis, which is yet another historical power imbalance (Nakamura *et al.*, 2023). All these factors that I have presented above converged to shape the research epistemology, methods undertaken, and importantly, the results found, something which must not be forgotten when situating this study in the broader literature on culture and LULCC across the Brazilian Amazon in years to come.

"What role did country play in Brazil's social transformations and in changes in its relations to what it took to be an outside world? How did this rural musicality give shape to political, economic, and communicative domains?"

(Alexander Dent, River of Tears: Country Music, Memory, and Modernity in Brazil, 2009:3)

Chapter 2: Country music popularity on local radio-stations is associated with cattle and forest loss across the Brazilian Amazon

Jordan O. Lafayette [1], Luke Parry [1], Christopher D. Ives [2], Jeffrey Hoelle [3] and Carlos Valério Aguiar Gomes [4]

[1]Lancaster Environment Centre, Lancaster University, Lancaster, UK

[2]School of Geography, University of Nottingham, Nottingham, UK

[3]Department of Anthropology, University of California, Santa Barbara, CA, USA

[4]Amazonian Institute of Family Agriculture, Federal University of Pará, Belém, Brazil

Chapter Acknowledgements

I would like to sincerely thank both Gabriel Silveira and Professor Lonán Ó Briain for their early contributions to the understanding of music as a form of cultural expression through informed conversations and active listening sessions to guide the interpretation of musical genres during data collection. Additionally, I would like to thank Thiago Jesus Fonseca for providing road network data, Lucas Alencar for sharing R code on hotspot mapping and land-use change, and Felipe Melo for providing guidance on statistical analyses in the early stages of data analysis.

Author contributions

All authors contributed to the conceptualisation of this research. J.O.L performed the research and wrote the first manuscript draft; all authors provided comments, while J.O.L., L.P. and C.D.I. edited the current manuscript.

Abstract

Tropical deforestation is a major driver of biodiversity loss and global climate change. Anthropological scholarship is beginning to influence how conservation science and sustainability science understand land-use decisions, and ethnographic research in Amazonia suggests an important role of 'cattle culture' in influencing local perspectives towards pasture and its expansion through deforestation. This study addresses an important research gap by undertaking the first quantitative, large-scale assessment of cattle culture, pasture and deforestation in Amazonia. Specifically, we adopt a cross-sectional research design (akin to a space-for-time-substitution), using present-day spatial cultural variation in municipalities across Amazonia as an analogue of potential cultural change over time in places which are experiencing cattle-based agricultural expansion and related deforestation. We assess musical preferences in order to characterize cultural variation, using play-time on local radio stations as a proxy for preferences towards genres associated with cattle, traditional Amazonian music, and others. We identified the genre of 3,427 songs played on 1069 radio stations in 375 municipalities (analogous to a US County) in 6 months in 2023 (mean ± SE of songs per station) and compared this with secondary data on deforestation and land-use, agricultural activity, and demographics. Brazilian country music (Sertanejo) was particularly popular in municipalities with large cattle herds, and this finding is robust to controlling for in-migration and geographic context. Furthermore, the genre was more popular in municipalities with higher cumulative deforestation (i.e. later frontier stages). Finally, Sertanejo dominated in over half (54.9%) of all municipalities and was associated with lower diversity of radio-play time for other musical genres. This study demonstrates how cultural variation can be quantified in order to understand its role in environmental change.

2.1 Introduction

Tropical deforestation is a major driver of global greenhouse gas emissions, biodiversity loss, climatic variability (Pendrill *et al.*, 2022) and often occurs in tandem with rights infringements of the rights and risks to livelihoods of local and indigenous communities (Seymour and Harris, 2019). Amazonian deforestation surged in the late 2010s, reaching heights unseen since the early 2000s (de Area Leão Pereira *et al.*, 2020). Various policy interventions have attempted to reduce tropical deforestation worldwide, generally focussing on economic incentive-based mechanisms such as the carbon financing associated with REDD+. This, however, can underestimate the complexity of social-ecological systems, and the solutions needed to combat multifaceted problems, such as tropical deforestation (Preiser *et al.*, 2018). Moreover, carbon financing often leads to significant elite capture of investments and the exclusion of forest communities (Corbera and Schroeder, 2011). Effective, and long-lasting interventions in deforestation contexts (generally payments for ecosystem services) are scarce (Chan *et al.*, 2017). This is perhaps because conservationists and others have hitherto struggled to include a diverse array of perspectives, worldviews, or ways of thinking when designing interventions (Mace, 2014).

The importance of engaging broader worldviews in achieving conservation targets is slowly being recognised (Raymond *et al.*, 2023). Although most historical arguments to conserve nature have focused on nature's economic capital (Costanza and Daly, 1992), recent work highlights the locally-defined cultural importance of nature (Gould, Morse and Adams, 2019). The latest values assessment by the International Panel on Biodiversity and Ecosystem Services (IPBES) expanded the conceptualisation of these concepts in mainstream conservation discussions, to formally include broader worldviews and ways of coexisting with nature (Anderson *et al.*, 2022). Critically, economic and instrumental values have been privileged in environmental management to date, yet recent findings suggest that expressed environmental values also emerge from deeper worldviews, embedded within cultural frameworks (Chan *et al.*, 2020). Yet, despite increased recognition of the cultural importance of ecosystems to people, and the role that personal values (formed in part by cultural norms) play in sustainability, it is not widely acknowledged that culture plays an important role in conservation challenges and potential solutions (Hodel, le Polain de Waroux and Garrett, 2024).

Human-nature relationships, guided by cultural values of communities are an important, yet overlooked element of land-use decisions (le Polain de Waroux *et al.*, 2021). Cultural values are the shared beliefs, principles, and standards that guide the behaviour, interactions, and decision-making of people within a particular community or society. These values reflect what a culture considers important, desirable, and morally right (Kluckhohn, 1951). Maller (2021) shows how cultural values can determine pro-environmental behaviours, raising questions around how culture can influence land use decisions, and therefore landscapes (Westerink *et al.*, 2021). Cultural norms concerning land use may also be affected by economic circumstances, or the weakening of juridical processes (Schmink *et al.*, 2008). In the Brazilian Amazon, traditional identities based in forest-based practices (e.g., rubber-tapping or Brazil nut harvesting) have been eroded in favour of livelihoods based on agriculture and cattle-raising (largely small-scale) (Salisbury and Schmink, 2007). The shifting livelihoods and identities of forest-proximate people are not solely due to economic transitions and may also relate to changing cultural values. Despite conservationists tending to assume cultural values towards nature are necessarily positive, some values can encourage negative attitudes towards 'unmanaged' natural landscapes and can be positive towards unsustainable land-use practices including extensive cattle-raising (Hoelle, Gould and Tauro, 2022).

The importance of culture in Indigenous land-use decisions and environmental stewardship is well recognized (Demmer and Overman, 2001; Schang *et al.*, 2020). Heckenberger et al., (2007) argue that the Amazon rainforest is a 'cultural landscape', crafted over millennia by land-use choices guided by indigenous cultural practices. Despite growing evidence that positive cultural values towards nature are a potential pathway to sustainability (Meijaard *et al.*, 2013; Tew, Simmons and Sutherland, 2019; Wu, 2019; Azzopardi *et al.*, 2023), there is still reluctance to accept culture as an important determinant of environmental outcomes (Caldas *et al.*, 2015; Zycherman, 2016; Hoelle, 2018; le Polain de Waroux *et al.*, 2021; Hodel, le Polain de Waroux and Garrett, 2024). In environmental economics, for example, farmers are generally narrowly conceived of as rational economic actors, responding to external economic drivers (e.g. the gate price of timber, beef and soybeans) and their own assets and capacities, which together determine land-use decisions (forest clearance, investments in cattle or mechanized agriculture) (Deininger and Minten, 2002). Decades of social science research have illustrated the short-sightedness of viewing humans as individualized, rational, self-maximizing economic actors (Sen, 1977). Sen argued that

people act from interests (in the sense of being reasoning agents who deliberate about economic and other kinds of values) and commitments, often sacrificing utility gains for principles (we are also moral beings), obligations or social norms (we are social beings, too). The implication for deforestation and environmental change in Amazonia and elsewhere is that real-world choices about land-use change are shaped not just by micro- and macro-economic conditions but by morals, interpersonal relationships and shared social norms, and formal and informal institutions.

Culture generally refers to people's learned and shared behaviours, and beliefs about what is desirable (Miller, 2011). Culture is essentially what we collectively think and do, how we represent ourselves and ultimately, the different ways by which we (as groups or communities) live (Boas, 1932). It is both tangible and intangible, via expressions of culture (e.g. music, clothing, art) and collective belonging to a culture through heritage (collective knowledge, values, recipes, rituals etc) (Zagaria, 2021). Group cultures can be tethered to geographic locations or landscapes that have helped to cultivate global cultural diversity (Kottak, 1999). Landscapes – including farm-forest landscapes at Amazonian deforestation frontiers – are imbued with culture, contributing to the development of new heritage, stories and ways of living (Wu, 2010). Cultures are forever evolving, morphing and taking up new iterations, anchored in new experiences and place-based collective identities (Cabana, 2011). Cultural values associated with historical landscapes and idealized ways of living attached to those landscapes are often brought into new landscapes (Seweryn, 2007), including ways in which migrant colonist farmers carry their cultural values with them when opening pastures and cropland at Amazonian deforestation frontiers. Group cultural structures may be fundamentally altered, and thus, the ways that people relate to their local natural environment, and what is considered 'ideal' in that environment (Milton, 1997; Plumwood, 2006). Cultural and individual values can be altered by the alteration of social group composition (through migration, ageing, or other factors), which can lead to environmental change (Kendal and Raymond, 2019).

In this article, we examine the prevalence of cattle culture in the Brazilian Amazon, referring to a way of seeing the world that is framed by positive cultural (in the sense of being shared) constructions associated with cattle (Hoelle, 2014). Amazonian cattle culture has spread due to the exponential growth of the cattle herd in the Brazilian Amazon (around a 10-fold increase in head of cattle since around 1960, reaching 93 million in 2020), but the

dissemination of the culture itself began with the in-migration of colonist farmers from Southern and Central-West Brazil (Fearnside, 2008; Hoelle, 2011). Indeed, Brazil's military dictatorship (1964-1985) supported large-scale colonization through building new Highways and settlements, subsidizing large-scale cattle-ranching and agricultural innovations, and framing Amazonia as an empty physical and (by implication) also devoid of civilization and culture); "Land without people for people without land" (Hecht and Cockburn, 1989). New cultural traditions based on previous, place-based identities are formed in new landscapes, in this case the *gaúcho* identity from southern Brazil, that continues to be transposed onto Amazonian landscapes (Oliven, 2000). Cattle culture encapsulates the cultural phenomena associated with legendary cowboys, traditionally from the Southern plains (Oliven, 2008), albeit with altered characteristics linked to their new environmental context.

A central feature of cattle culture are the ways that people express their connection to rural lifestyles (Hoelle, 2014). The rise in popularity of rodeios (rodeos), cowboy hats, boots, and belts, and the churrasco (barbeque) are symptoms of a broader way of seeing the world that is directed by a relation to cattle ranching (Hoelle, 2015). Brazilian country music, or Sertanejo, is also central to this cultural expression (Lima, 2019). The lyrical content and themes present in traditional Sertanejo music, or *sertaneja raiz*, idealise country living, or longing for a rural lifestyle (Dent, 2009). Demonstrating the broader influence of music, a 1961 musical hit "King of the Cattle" which portrayed a cattle rancher's pride and connection to the land, inspired a popular 1996 Brazilian telenovela series of the same name, set on an Amazonian ranch. Sertanejo music tends to reinforce the cultural narrative of prosperity and tradition associated with cattle ranching, which shapes this cultural group's shared, often-negative, views towards the 'pre-cattle' landscape; intact primary rainforest. Critically, this desire to live a rural lifestyle, in which land is cultivated and pasture maintained, may be disseminated through lyrical messaging and themes in Sertanejo, including in emerging contemporary sub-genres such as *Agronejo* (a fusion of Sertanejo, funk and electronic music) whose lyrics often glamorize agribusiness. Interestingly, ideas regarding land cultivation, maintenance and ultimately, progress, are central to the cultural values associated with deforestation frontiers (Hoelle, 2018).

Music, as a facet of culture, permeates daily life, informs fashion and language, and mirrors personal tastes. Preferences for specific musical genres are therefore important in shaping individual identity (Bennett, 1999). In Brazil, music is a vital medium for conveying cultural

meaning, particularly within traditional rural settings (Leu, 2006; Barbosa, 2021). Furthermore, music is considered to exert a stronger influence than other cultural elements on how individuals express themselves publicly and on their personal values, including political and religious beliefs (Fingerhut *et al.*, 2021). Research on specific music genres in Western societies — such as Punk and Hip-hop — demonstrates the powerful role music can play in shaping and advancing social movements (Tillman, 1980). The messages conveyed through music can sometimes override existing value systems, as the ideals expressed in the music come into tension with an individual's lived experience (Lamy and Levin, 1985). We employ these sociocultural insights from anthropology and musicology to examine cattle culture in the Amazon in relation to the cultural representation of *musica sertaneja*, Brazilian country music (Hoelle, 2015).

Examining variation in cultural values across geographically extensive and culturally diverse deforestation frontiers requires drawing on methodological innovations from across disciplines, going beyond anthropology's traditional dependence on in-depth small-scale ethnographic research. Helpfully, demographers have utilized big data on distinct social groups to outline potential pathways for understanding culture and cultural shifts at large-scales. Waters and Jiménez's (2005) literature review demonstrated how new immigration pathways into the USA influence the cultural assimilation of migrants with local people through language assimilation, intermarriage, socioeconomic status and spatial concentration. Stewart et al. (2019) used Facebook market data on self-reported interest in musical genres to show that first and second-generation Mexican-Americans can show strong assimilation into US culture, despite widespread political critiques of the group's lack of willingness to adopt American cultural norms. Vieira et al. (Vieira *et al.*, 2020) similarly used Facebook data to measure the global spread of Brazilian culture overseas through stated preferences for Brazilian dishes among Facebook users, identifying how shared food preferences can influence the 'cultural distance' between countries. Thus far, however, these approaches have been limited to urban settings, and largely to non-remote places in the Global North. Consequently, these quantitative methods have not been applied in conservation contexts in the Global South in which rapid environmental change may be interwoven with shifting cultural values towards biodiversity-rich forest landscapes and human-dominated agricultural landscapes such as cattle pasture.

Here, we evaluate cultural change across Amazonian deforestation frontiers, using municipality-scale musical preferences as a proxy for identifying and representing distinct cultural patterns. We ask the following research questions to do this:

1. How popular is Sertanejo country music across the Brazilian Amazon, relative to other genres?
2. What is the relationship between Sertanejo music popularity and local deforestation?
3. What is the relationship between Sertanejo music popularity and local cattle-raising activity, and to what extent can this relationship be attributed to the cultural diffusion of cattle-related practices versus the demographic influence of in-migrants from outside Amazonia?

2.2 Methods

2.2.1 Study Area

We used publicly-accessible radio stations to collect song data for 335 municipalities (analogous to US counties) across the Brazilian Amazon in order to capture as much variety as possible in the relative amount of forest cover, deforestation, and cattle pasture (Figure 1). Municipalities are composed of a rural territory with an urban centre of the same name, and provide a political and territorial border at which environmental and political decisions are made in Brazil, a highly decentralised country. The Legal Amazon, hereafter called Amazônia Legal, comprises 772 municipalities, across nine states (Acre, Amapá, Amazonas, Maranhão, Mato Grosso, Pará, Rondônia, Roraima and Tocantins). All municipalities in all Amazonian states except for Maranhão were included in the initial sampling design (n = 591). Maranhão was excluded because much of the state is already heavily deforested, with as little as 24% original forest cover remaining in the entire state by 2019 (Silva Junior et al. 2019). Due to network outages or the loss of network coverage (meaning some radio stations were offline) part way through sampling, the final sample was 335 municipalities. We also utilized publicly available secondary data on cattle, pasture, proximity to roads, forest cover and deforestation data from official sources (Brazilian Institute for Geography and Statistics [IBGE], National Institute for Space Research [INPE]) and the well-respected MapBiomas land-use land cover database.

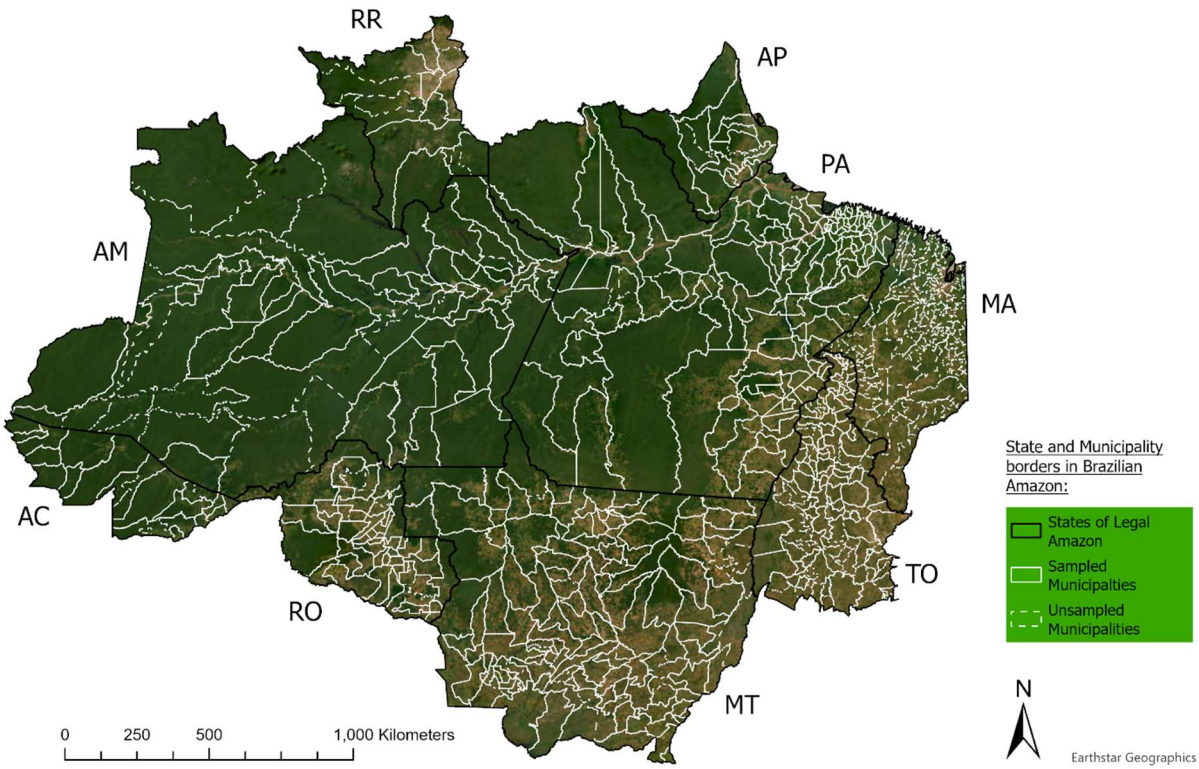


Figure 2.1. Satellite imagery (ArcGIS Pro, ESRI, 2025) showing land-use and land-cover of the Legal Amazon Biome (AC, Acre; AM, Amazonas; AP, Amapá; MT, Mato Grosso; PA, Pará; RR, Roraima; RO, Rondônia; TO, Tocantins). *All municipalities within the Legal Amazon are outlined with white dashed lines, showing unsampled municipalities (n = 437), while sampled municipalities (n = 335) are shown with solid white lines. Importantly, Maranhão was excluded from initial sampling effort due to high historical deforestation of many municipalities, and therefore the final sampling effort aimed to capture song data from 591 municipalities, meaning that data was acquired at a success rate of 57%.*

2.2.2 Data Sampling

Musical preferences were assessed by counting the number of songs of different genres played in municipalities, utilizing the music played on geolocated radio stations (i.e. the municipality in which a radio station was listed as being based in, on https://www.radios.com.br/). We aimed to identify the musical genre of 10 songs for each municipality, imposing a quota on the number of songs listened to on each radio station if there were multiple available online for a given municipality. First, we compiled a list of all radio stations within each municipality that had an online presence (n = 1169), a live weblink, and the name of each radio station if a municipality had more than one. Where a municipality

had only a single radio station, we aimed to collect 10 songs from that station. In cases where no radio station was available, no data was collected. Song data was initially collected during 110 sessions of around 60-to-90 minutes each from February to July 2023. This resulted in song data being collected for 335 municipalities out of a potential 591 (see Supplementary Table S2). In each session, the PI used an audio recording phone app to record live radio played online. We used the music identification application Shazam to try and identify the genre of each recorded song. An extra 20 sessions were conducted between August – September 2023 to balance sampling effort (i.e. song count number) across municipalities. Each municipality was assigned 10 lines in our dataset labelled 'song 1' to song 10' chronologically. Songs were found by tuning into live local radio station shows at random times of day, using https://www.radios.com.br/. To avoid spatial bias in our data, we sampled 'song 1' for each municipality randomly until each municipality had one song (expressed here as an observation). This process was then repeated for each of the 10 songs (i.e. skipping randomly between municipalities after each song), until each municipality had 10 observations. In a typical data-collection session we listened to live radio from approximately 9 radio stations and recorded a total of around 31 songs, pending genre identification. At the time of observation, multiple pieces of information were recorded about the song. To identify the song, the Shazam web browser extension was used in real time. When Shazam successfully classified a song, we recorded the song name, artist, genre of the song according to Shazam, the time of recording (GMT/BST) and the date of recording. For songs that were unable to be verified by Shazam (n=253), the song was marked as 'Unclassified' and a recording of the song was provided to a Brazilian musician and musical expert based in the Amazon for genre classification (https://www.instagram.com/gabrielsilveira_____/). For radio stations where a song was not playing at the time of recording, the song was marked as 'news', and a further observation was taken at a later date.

Musical genre classification: Genre information for all songs was taken from the Shazam classification of the song at time of recording. Genre data was later narrowed down to account for overlaps between genres. Following this process, we narrowed our genre list to 33 unique genres from an initial list of 75. Where no genre information was available (such as with unclassified songs), we highlighted these songs and an independent genre classification was carried out by a Brazilian musician from Amazônia using recordings of each 'unclassified' song. In order to validate the consistency of genre classifications and the musical expert, we also asked them to classify an additional 25 songs for which we had a

Shazam classification. These songs were randomly selected from across municipalities and the genre list, and were done blind in the sense that we shared de-identified recordings without the song, artist name, or genre. We observed no discrepancies (i.e. there was 100% concordance between the two classification methods).

In order to more clearly examine music as an indicator of cultural dynamics, as well as contemporary debates surrounding musical genres and their classification, we spoke with musicology scholars based in the United Kingdom and United States with expertise in South American musical genres and origins, as well as Brazilian musicians/musical experts. These conversations clarified the complex nature of genre classifications in current musicology scholarship. Genre is determined by a number of specific characteristics, not limited to but including: rhythm, tempo, instrumentals and other acoustic factors (Nanni *et al.*, 2016). Machine learning algorithms (such as those employed by Shazam) used by the public to classify the genre of songs often use these musical characteristics to do so (Pelchat and Gelowitz, 2020; Ghosh *et al.*, 2023). Shazam was described as particularly adept at classifying popular musical genres using this technology (Ghosh *et al*., 2023).

We re-classified musical genres into relatively broad clusters based on grouping together any similar genres which Shazam may classify as distinct by Shazam. For example, we combined ‘Brazilian’ with ‘Musica Popular Brasileira (MPB, Popular Brazilian Music) because they both broadly focus on popular (pop) songs in the Brazilian mainstream and share similar musical characteristics. We combined all sub-genres of ‘Sertanejo’ (Brazilian country), given the similarity in lyrical themes and storytelling across most genres of Sertanejo (Godoi Barroso and Forattini, 2020), in addition to their similar instrumentality. This decision to “group not split” genres drew on literature highlighting the common themes and symbolism across the numerous sub-genres of Sertanejo (Dent, 2009; Barbosa, 2021), and our conversations with Brazilian music experts in Amazônia.

2.2.3 Data Analysis

All analysis was conducted using the statistical platform RStudio 2023.06.1. We used packages ‘sf’ and ‘geobr’ to construct our visual representations of cultural variation in space. We downloaded and filtered all polygons directly from the IBGE database (Brazilian Institute of Geography and Statistics) for municipalities in the eight Amazonian states included in this study. For our statistical analysis we filtered out 256 municipalities with partial (i.e. < 8

songs) or zero song data (see Supplementary Table 1). The final count of municipalities included in this analysis was 335. We tested the count of the most popular musical genre overall (Sertanejo) per municipality, and the number of unique genres observed per municipality for these analyses. These two variables constitute our outcome variables for later tests reported in this section.

Research Question 2.1) How popular is Sertanejo country music across the Brazilian Amazon, relative to other musical genres?

First, we applied Principal Coordinate Analysis (PCoA) to ordinate municipalities based on their musical genre profiles, allowing us to visualize similarities and differences between how musical genres were played on local radio stations. To further identify groups of genres with similar profiles, we applied hierarchical clustering to the PCoA coordinates and visualised the results as a dendrogram, using a hierarchy of 0.77 to define three meta-clusters, which was indicated to be the optimal amount of clusters for our data by the 'optimal_clusters' function in R. This combination of ordination and clustering allowed us to capture both the continuous gradient of genre similarity among municipalities and higher-order structures in musical preferences.

To understand the diversity of musical genres at municipal level we used the Shannon-Wiener index. This index estimates the abundance and evenness of species (in our case, musical genres) across study locations (municipalities) (Heip, Herman and Soetaert, 1998). Abundance refers to the amount of genres present in each municipality, and evenness refers to the proportion that each genre is of the total number of genres, and was calculated by considering the number of individual observations of each unique genre and their proportion of total observations (Nolan and Callahan, 2006). Plotting these diversity values allows us to visualize how the prevalence of Sertanejo compares to other genres across municipalities, addressing RQ1 by highlighting areas where Sertanejo is dominant versus those with a more even distribution of musical genres.

We then mapped the spatial distribution of Sertanejo observations (i.e. song count), our most popular genre across all municipalities. We used the proportion of total observations per municipality that were recorded as Sertanejo to show relative popularity of Sertanejo across all sampled municipalities. These results were then plotted (0-1) using gradient shading in a map of all municipalities with complete data. We tested for spatial autocorrelation in our song

count data because spatially close municipalities may have more similar musical profiles, which could violate the independence assumption of standard statistical analyses (Shaikh *et al.*, 2021). Spatial autocorrelation arises when values of a random variable, whether similar or dissimilar, cluster together in a specific area (Anselin, 1995). The concept is synonymous with Tobler's first law of geography, which asserts that everything is interconnected, but objects that are closer together in space are more closely related than those that are farther apart (Tobler, 1970). Additionally, spatial correlation is common in land-use datasets (Alencar, Parry and Melo, 2025) and in order to obtain robust results that took this into account, we used Moran's I test to assess potential spatial autocorrelation in the count of Sertanejo observations at municipality level. Moran's I is a measure of spatial autocorrelation that quantifies the degree to which similar values of a variable cluster together spatially. It identifies patterns in geographic data by comparing the variable's value at one location with the values at neighbouring locations (Moran, 1950).

We then tested for spatial clustering of the Sertanejo song count data using the Getis-Ord Gi* statistic, to reveal potential Sertanejo cold- and hot-spots (Dlamini *et al.*, 2021). Getis-Ord Gi* generates 'hot spots' by creating z-scores and P-values for each 'feature', which in our case is per municipality. We used the percentage of total songs recorded as Sertanejo as our common unit of measurement. Hotspots are taken to be significant if a municipality has a high Gi* value and is surrounded by municipalities with high values, while cold spots are taken to be significant if a municipality is surrounded by municipalities with low Gi* values, and has a low value itself. For further statistical analysis in this study, we accounted for these effects in our model terms when testing statistical relationships between Sertanejo observations and land-use data.

Research Question 2.2) What is the relationship between Sertanejo music popularity and local deforestation?

We obtained forest cover and deforestation data for 1988 - 2023 from a widely used official source from Brazil's National Institute for Space Research (INPE), the PRODES remote sensing product. We downloaded deforestation and land-use change data for a period of 5 years between 2016-2021. We ran correlation analysis between the count and proportion of Sertanejo songs per municipality against deforestation data, using Spearman's rank correlation to account for the fact that our song count data followed a Poisson distribution and was thus not normally distributed (Hauke and Kossowski, 2011).

We used a negative binomial generalized linear model (GLM) to understand the relationship between the count of Sertanejo songs and relative forest remaining across all municipalities. This was done by controlling for total land area (km^2) in the model as a covariate with the total forest cover remaining in December 2023. This method was chosen because including proportional forest cover (which was the only covariate that was correlated [negatively] with Sertanejo prevalence) violates statistical assumptions for negative binomial GLM's (Breslow, 1996). Although we observed a negative relationship between the proportion of original forest remaining in a municipality and the prevalence of Sertanejo songs in negative binomial models, we focused our main analyses on cattle herd size rather than forest. This decision is justified because forest cover and cattle herd size are strongly negatively correlated across municipalities (Spearman's ρ [rho] = $-0.51, p < 0.001$), meaning that including both in the same model would potentially be redundant. Moreover, cattle herd size is directly tied to the cultural practices associated with Sertanejo, making it a more proximal and theoretically meaningful predictor of music popularity. In subsequent models, we therefore explore the relationship between Sertanejo prevalence and cattle while controlling for socio-spatial covariates such as in-migration and distance to major cities.

Research Question 2.3) What is the relationship between Sertanejo music popularity and local cattle-raising activity?

Agricultural data was collected from online archives of the IBGE, including head of cattle (and other animals) and pasture area. We also used spatial data on the presence or absence of roads/highways (e.g. Trans-Amazon Highway) per municipality (provided by project partners in Brazil), and demographic migration data (specifically, the percentage of a municipality's population in 2023 that was born outside of that municipality), which was acquired from IBGE. These covariates were included in the final control model because of their positive correlation with Sertanejo count data in our dataset in exploratory data analysis (Supplementary Figure 2.4). Additionally, some musical genres captured by our data collection method are associated with more urban metropolitan contexts (e.g. Rap, Funk, Dance/EDM), and so the distance (km) to the nearest large city (≥ 100k inhabitants) was used as a control variable in statistical modelling.

First, we tested spatial clustering of cattle herd size data using hotspot analysis, similar to RQ2.1 for Sertanejo. This allowed us to identify whether municipalities with larger cattle herds were spatially clustered across the Amazon and to visually compare these clusters with

Sertanejo hot- and cold-spots (see Figure 2.4 for the Sertanejo map). To maintain comparability with the musical analysis conducted cattle herd size data was omitted for municipalities where we did not have >8 songs (well sampled municipalities). This provided a useful visual framework to explore potential overlaps between municipalities with high Sertanejo prevalence on local radio stations and those with large cattle herds, supporting subsequent correlation and regression analysis for research question three. To assess whether cattle herd sizes differed across hotspot classifications, we first performed a Kruskal-Wallis non-parametric test, followed by Dunn's post-hoc test with Bonferroni adjustment for pairwise comparisons. This approach allowed us to determine whether the distributions of herd sizes were significantly different across classification groups, and to identify which specific groups differed from one another.

We used negative binomial generalized linear modes to understand which of our covariates best predict a high proportion of Sertanejo observations (≥ 0.75 of all songs recorded) at municipality-level. We ran binomial models using the 'cbind' function to combine our two categories, the count of Sertanejo songs and non-Sertanejo observations into a single matrix. This combined matrix was then used as our response variable in the regression models to facilitate our analysis of the relationship between our predictor variables (Log of cattle herd size, Euclidean [straight line] distance (km) to nearest large city with over 100k inhabitants [measured from the municipal centroid], and the number of migrants per 100 inhabitants) and the proportions of our response variable, the count of Sertanejo songs per municipality. We ran three models, each building on the last in terms of included variables. Model 1 included only the Log of cattle herd size in 2019, Model 2 then included the other covariates, and finally, following previous analysis that identified spatial autocorrelation in the Sertanejo song count data (see Figure 2.4, hotspot analysis), Model 3, which included a spatial lag covariate to account for spatial autocorrelation in the response variable. We ran a Likelihood ratio test to understand how each of our models performed against one another in terms of their fit with the Sertanejo data. Because the models were estimated using a log-link function, all coefficients were exponentiated to interpret their effects on the original outcome scale as multiplicative changes in the expected count.

2.3 Results

RQ1.1) How popular is Sertanejo music across the Brazilian Amazon, relative to other musical genres?

We recorded 3,427 songs from 1,069 unique radio stations in 375 municipalities (mean = 3.19 ± 0.15 SE radio stations in those municipalities). From the 335 well-sampled municipalities (≥ 8 songs recorded in each) we recorded 3,245 songs which covered 33 unique genres; n = 75)(Supplementary Table 2.1). Ten genres accounted for 93.2% of songs, including Sertanejo (31.3% of all songs), followed by Gospel (21.1%), Música Popular Brasileira (MPB, 13.7%), International Pop (10.1%), Forró (5.6%), Rock (3.2%), Dance (2.9%), Pagode (2.3%), Latino (1.6%) and Alternative (1.4%) (Table 2.1). Sertanejo was the most popular genre for 55% (184/335) of municipalities, followed by Gospel (27.5%) and MPB (10.2%). At least one Sertanejo song was recorded in 87% of the well-sampled municipalities.

Table 2.1. Popular musical genres (top 10) played on radio stations in 335 municipalities in the Brazilian Amazon.

	Total Songs		**Cumulative % of All Songs**	**Municipalities where Genre was most popular**		**Mean Rank (Municipality)**	**Songs and unique genre count**	
Genre	*N*	*%*	*%*	*N*	*%*	*(lower = more popular)*	*Spearman's Rho*	*P-values (Bonferroni adj.)*
Sertanejo	1015	31.3	31.3	184	54.9%	1.56 ± *0.05*	-0.24	*<0.001*
Gospel	684	21.1	52.4	92	27.5%	1.78 ± *0.06*	-0.15	*<0.05*
MPB	444	13.7	66.1	34	10.2%	2.21 ± *0.06*	0.28	*<0.001*
Pop	327	10.1	76.2	15	4.5%	2.33 ± *0.06*	0.36	*<0.001*
Forró	183	5.6	81.8	5	1.5%	2.57 ± *0.07*	0.34	*<0.001*
Rock	105	3.2	85	1	0.3%	2.87 ± 0.09	0.27	*<0.001*
Dance	93	2.9	87.9	3	0.9%	2.89 ± *0.12*	0.30	*<0.001*
Pagode	74	2.3	90.2	0	0.0%	2.97 ± *0.10*	0.23	*<0.001*

Latino	52	1.6	91.8	0	0.0%	3.14 ± *0.09*	0.15	*<0.05*
Alternative	44	1.4	93.2	1	0.3%	2.91 ± *0.15*	0.18	*<0.01*

We identified a mean of 4.7 (± 0.1 SE) genres per municipality, from a mean 9.7 (± 0.33 SE) songs each in the well-sampled municipalities. The number of genres per municipality was negatively correlated with Sertanejo song count (Table 2.1; $p < 0.001$), suggesting that Sertanejo music dominates the musical mix of radio stations when it is present. There was a negative correlation between unique genres and Gospel song counts (Table 2.1; $p < 0.05$), which also suggests dominant tendencies of this genre. Song counts for all other top 10 genres were positively correlated with genre counts at the municipal level. The number of unique genres across all municipalities showed a normal distribution for our sample (Shapiro-Wilk test p = 0.5064) (see Supplementary Figure 2.1). Sertanejo song count per municipality was negatively correlated with the count of all other genres, with the strongest negative association being between Sertanejo and Gospel song co-occurrence (Supplementary Figure 2.2). The co-occurrence of some genres was positively correlated (Forró and MPB, Rock and Pop, Dance and MPB), suggesting that some genres are likely to be played as part of a more varied selection of music at the municipal level compared to Sertanejo and Gospel, respectively.

Individual musical genre profiles differed among municipalities, with three clusters being identified by a Principal Coordinate Analysis Ordination, each dominated by either Sertanejo, Gospel, or Popular Brazilian Music (MPB). The first Principal coordinate explained 10.4% of the total observed variance, with the second and third accounting for 6.2% and 5.7%, respectively (22.64% in total). The first five coordinates explained 32.5% of the cumulative variance in our dataset. Municipalities that were more closely aligned with the Sertanejo genre cluster profile were generally found within Cluster 3, although some also overlapped with Cluster 1 and 2 respectively (Figure 2.2). Most genre profiles were clustered together from our analysis, although some genre profiles showed significant dissimilarity from one another, namely MPB, Gospel and Sertanejo.

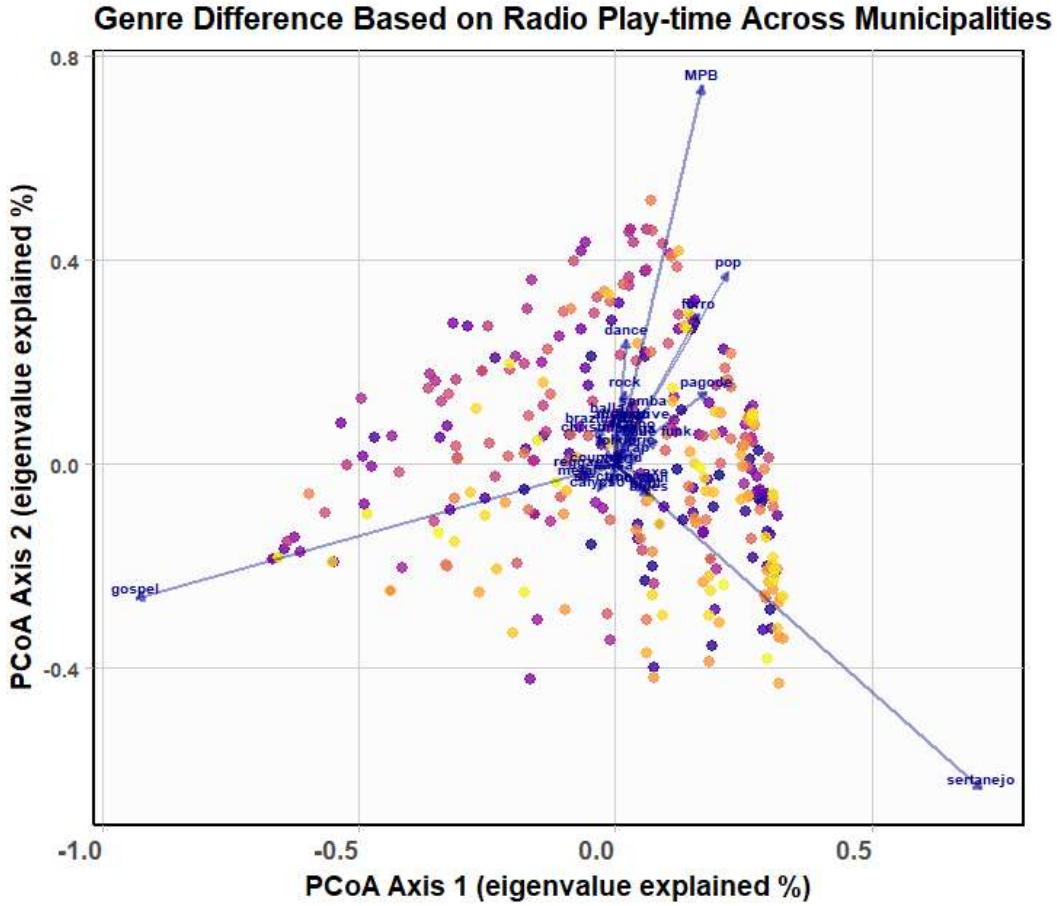


Figure 2.2. PCoA ordination plot of municipality clusters with arrows displaying musical genre distance based on municipal musical preference profiles based on song identification from local radio stations. *Each dot represents one well-sampled (≥8 songs recorded) municipality (n = 335).*

Musical genres were grouped into three meta-clusters, as suggested by the Dendrogram feature in R, based on a hierarchy cutoff of 0.77 (Figure 2.5). The largest cluster, comprising four subtrees, included seven of the ten most popular genres, including MPB, Gospel, and Sertanejo (see Table 2.1). While most genres formed a dense central cluster in the PCA, Gospel, Sertanejo, and MPB appeared as distinct outliers along PC1 and PC2, reflecting their stronger differentiation across municipalities. In the dendrogram, genres were grouped differently: the largest meta-cluster on the left included most of the highly popular genres (including MPB, Gospel, and Sertanejo), a smaller meta-cluster captured disco and soul, and a third meta-cluster contained the more diverse, less dominant genres. Within the left-hand cluster, Gospel formed its own subtree, while Sertanejo clustered most closely with Forró, consistent with their relative positions in the PCA loadings (Figure 2.2). Together, the PCA and hierarchical clustering reveal both the overall gradient of similarity among most genres

and the distinctive profiles of the dominant musical traditions. In summary, PCA showed most genres forming a dense central cluster, with MPB, Gospel, and Sertanejo standing out as distinct along the major axes. In the dendrogram, genres were grouped into three meta-clusters: the left-hand cluster contained most of the highly popular genres (including MPB, Gospel, and Sertanejo), a smaller cluster captured disco and soul, and a third, larger cluster included the more diverse, less dominant genres. This combination highlights both the continuous gradient of similarity among most genres and the distinctive hierarchical structure of the dominant musical traditions.

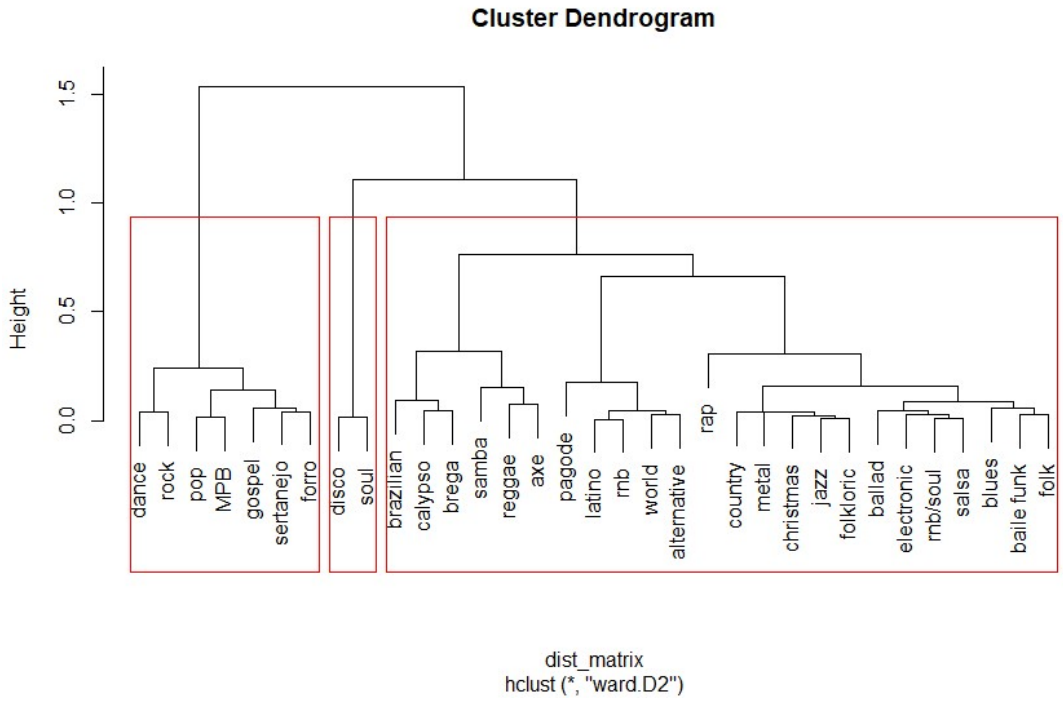


Figure 2.3. Hierarchical clustering of musical genres across municipalities, shown as a dendrogram with a hierarchy cutoff of 0.77 based on ward distance matrix. *Three meta-clusters were identified: the largest cluster (right) contains the more diverse, less dominant genres; a smaller cluster (left) includes most of the highly popular genres, including MPB, Gospel, and Sertanejo; and a third cluster (center) captures disco and soul. Within the left-hand cluster, Gospel forms its own subtree, MPB clusters most closely with Pop (reflecting patterns also observed in the PCA loadings), while Sertanejo clusters most closely with Forró.*

There was high variation in the diversity (richness and evenness) of unique musical genres observed at municipal-scale (Shannon-Wiener indices (H) ranged from 0 to 2.03 per municipality, mean = 1.30 ± 0.02 SE)(Supplementary Figure 2.3). The most diverse municipality was Acrelândia, Acre (H = 2.03, 8 unique genres including MPB, Sertanejo, Gospel, Pop and Pagode), and the least diverse was Anamã, Amazonas (H = 0.02, 1 unique genre, Gospel). Over one-third (34.9%) of municipalities demonstrated moderate diversity, with Shannon diversity index scores of above 1.5, whereas 3.6% of municipalities had an index score close to 0 (H < 0.1), and only 0.9% of municipalities had a score above 2. Municipalities within Pará state made up 50% of the top 50 Shannon index scores, with municipalities within Acre and Amazonas (12% each) and Mato Grosso (10%) also showing moderate diversity scores.

There was significant spatial autocorrelation in the song count of the most popular musical genre across all municipalities, Sertanejo (Moran's I = 0.289; $p = < 0.001$) and the proportion of songs that were Sertanejo per municipality (Moran's I = 0.298; $p = < 0.001$). Hence, municipalities where Sertanejo was popular tended to be surrounded by municipalities where this genre was also popular. However, there was no evidence of spatial autocorrelation in the number of unique genres per municipality (Moran's I = 0.027, $p = 0.1773$).

We identified significant Sertanejo hot spots and cold spots, composed of groups of municipalities with similar musical profiles (Global G statistic: 0.016, $p = < 0.001$) (Figure 2.3). There was a large variation in the number of municipalities assigned to each Sertanejo hotspot group, ranging from 'Very cold' (n = 120); 'Very hot' (n = 101); 'Neutral' (n = 73); 'Hot' (n = 21); to 'Cold' (n = 19). We found a large meta-cluster of Sertanejo music in south-central Amazônia, split into; (I) across Rondônia (RO), (ii) western Mato Grosso (MT), (iii) southeast Amazonas (AM), (iv) southwest Pará (PA). Cold spots for Sertanejo dominated northern Amazônia (north of the main Amazonas River channel in Amazonas State, Roraima, and Pará) with evidence of additional cold-spots in eastern Pará, central Amazonas, and parts of Acre.

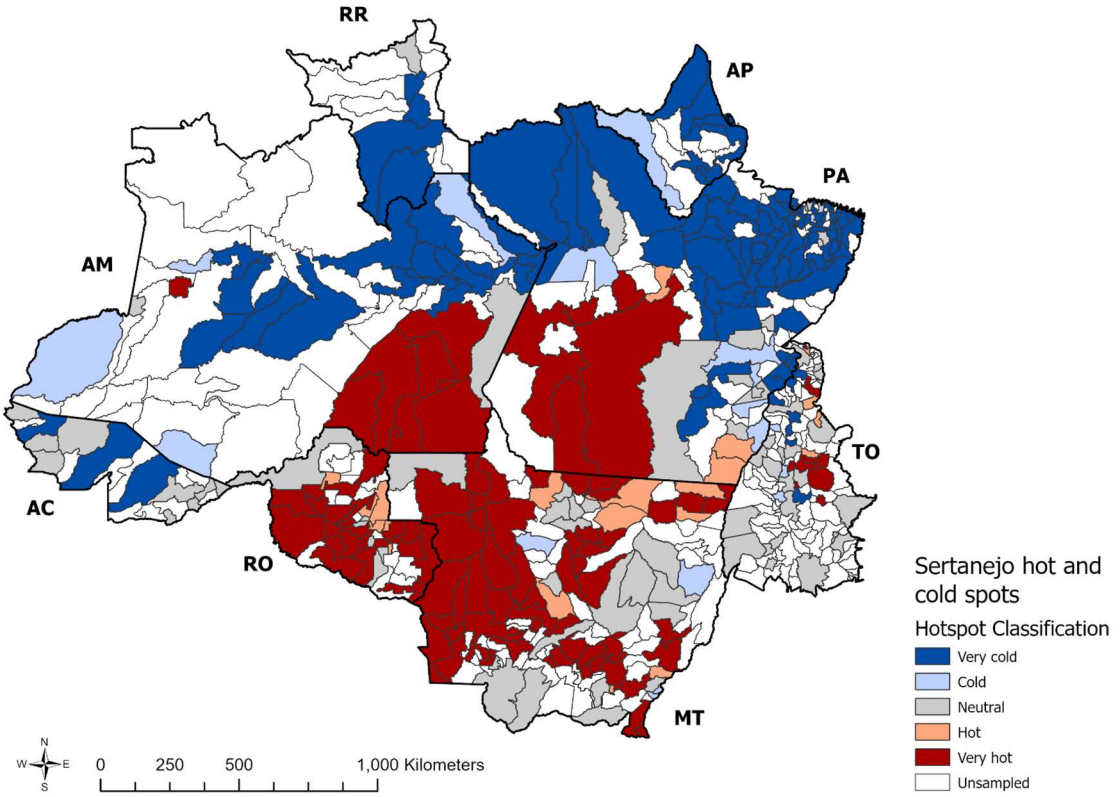


Figure 2.3. Spatial hotspots and cold spots of Sertanejo country music played on local radio stations across 335 municipalities in eight sampled Amazonian states. *Identified from Getis-Ord tests. Corresponding State Acronyms are shown adjacent to the state highlighted by the thicker black line (e.g. AM for Amazonas). Blank municipalities (White - shown as 'Unsampled' in Legend) represent municipalities with missing data, or insufficient data collected (<8 songs).*

RQ2.2) What is the relationship between the popularity of Sertanejo music and local deforestation?

More forested municipalities (i.e., those with a higher proportion of original forest remaining in December 2023) tended to have fewer Sertanejo songs played on local radio ($r(332) = -0.24$, $p < 0.001$; Table 2.2; Figure 2.4). However, Sertanejo song count was not significantly related to cumulative absolute deforestation (km²) before 2008 ($r(332) = 0.11$, $p > 0.05$) or between 2008 and 2024 ($r(332) = 0.04$, $p > 0.05$). Likewise, incremental deforestation between 2021 and 2023 showed no significant association with Sertanejo song count, with all coefficients small in magnitude (ranging from 0.04 to 0.06, all $p > 0.05$). These findings suggest that while Sertanejo is somewhat less prevalent in more heavily forested municipalities, its presence is not directly linked to recent or cumulative deforestation trends.

Instead, Sertanejo appears to be broadly popular across the region, remaining common even in municipalities that retain extensive forest cover (Figure 2.4).

When exploring the relationship between Sertanejo prevalence on local radio stations and the amount of forest cover remaining in December 2023, relative to the area (km²) of each municipality, negative binomial regression revealed a weak but statistically significant association ($\beta = -0.13$, SE = 0.07, $p < 0.05$), indicating that municipalities with more remaining forest tend to have slightly fewer Sertanejo songs. Importantly, the proportion of forest remaining is significantly negatively correlated with municipal cattle herd size (Spearman's ρ [rho] = –0.51, $p < 0.001$).

Overall, Sertanejo is somewhat less common in municipalities that retain more forest, but there is no clear relationship with recent or cumulative deforestation. Although there was a significant association between relative forest cover remaining and Sertanejo prevalence, taken together, these results suggest that factors other than forest loss are likely important factors in shaping local radio playtime. Importantly, given the significant negative association between forest cover and cattle herd size, it is plausible that cattle, rather than forest alone, may better explain variation in Sertanejo prevalence.

Table 2.2. Correlation matrix showing the correlation (Spearman's Rho) and p-value (Bonferroni adjusted) between count of Sertanejo songs played on local radio stations and incremental deforestation between 2021 and 2023, including total cumulative deforested area (km²).

Covariate	**Sertanejo Song Count** Spearman's Rho, *p-value (Bonferroni adj.)*
Total cumulative deforested amount (km²) 2008 to 2023	0.04, $p > 0.05$
Total cumulative deforested amount (km²) 1988 to 2007	0.11, $p > 0.05$
Proportion of original forest cover (1987) remaining 12/2023	-0.24, $p < 0.001$***
Incremental Deforestation 2021	0.06, $p > 0.05$

Incremental Deforestation 2022	0.05, $p > 0.05$
Incremental Deforestation 2023	0.04, $p > 0.05$

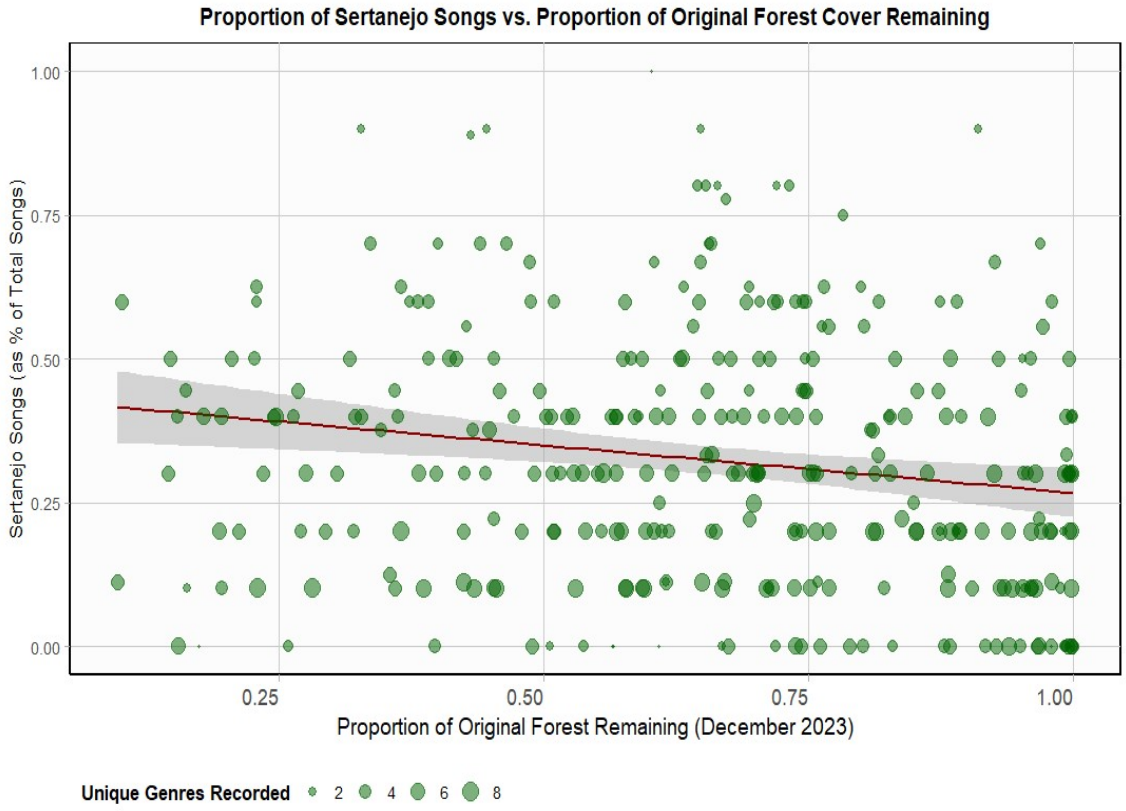


Figure 2.4. Bubbleplot of Sertanejo songs as a proportion of all songs recorded (per municipality) plotted against the proportion of original forest remaining (in 2024). *Line of best fit calculated using Generalized Linear Model, displayed with standard error shading. Bubble sizes are proportional to the number of unique genres recorded in each municipality.*

RQ2.3) What is the relationship between the popularity of Sertanejo music and local cattle-raising activity?

Municipalities with larger cattle herds (head of cattle) between 2019 and 2023 tended to have significantly more Sertanejo songs played on local radio stations in 2023 (Table 2.3). The correlations were all highly significant ($p < 0.001$ with Bonferroni adjustment) and positive (correlation coefficients ranged from 0.33 to 0.34) across this period. There were weakly significant positive correlations (correlation coefficients of 0.26 to 0.27, $p < 0.01$ in all cases)

between pasture area (km2) from 2019 through to 2023 and Sertanejo song count. Finally, the intensity of cattle-ranching (head of cattle per hectare of pasture [mean = 2.53 ± 0.61 SE]) was significantly positively correlated with the number of Sertanejo songs played. The correlation coefficients ranged from 0.29 (*r(332), p < 0.001*) in 2021 to 0.30 (*r(332), p < 0.001*) in 2020.

Table 2.3. Correlation matrix demonstrating correlation between count/proportion of songs that were Sertanejo songs, Cattle herd sizes and Pasture area (km2) between 2019 - 2023.

	Correlation with Sertanejo song count, corresponding p-value (Bonferroni adjusted) (on 332 degrees of freedom).				
Covariates	**2023**	**2022**	**2021**	**2020**	**2019**
Cattle herd size	0.3298, *< 0.001****	0.3294, *< 0.001****	0.3277, *< 0.001****	0.3356, *< 0.001****	0.3367, *< 0.001***
Cattle per hectare of Pasture	0.2923, *< 0.001****	0.2931, *< 0.001****	0.2889, *< 0.001****	0.2989, *< 0.001****	0.2960, *< 0.001****
Pasture area (km2)	0.2597, *< 0.01***	0.2644, *< 0.01***	0.2662, *< 0.01***	0.2658, *< 0.01***	0.2658, *< 0.01***

There were significant cattle herd hot spots and cold spots, composed of groups of neighbouring municipalities *(*Global G statistic: 0.038*, p = < 0.001)*. There were two meta-clusters of cattle herds across Amazonia (Figure 2.6). Similar to our analysis with Sertanejo hot spots and cold spots, these were between (i) Southern-Para; and (ii) across most of South-Eastern Amazonas and most of Mato Grosso, Rondônia and Tocantins. Again, cold spots for cattle showed similar patterns to our previous analysis, spread across northern Amazonia (north of the main Amazonas River channel in Amazonas State, Roraima, and Pará) with evidence of additional cold-spots in Amapá (AP), eastern PA, northern AM, and parts of Acre (AC), albeit to a slightly lesser degree.

There was a large variation in the number of municipalities assigned to each cattle hotspot group, ranging from 'Very hot' (n = 148); 'Very cold' (n = 83); 'Neutral' (n = 70); 'Cold' (n = 18); to 'Hot' (n = 14). The Kruskal-Wallis non-parametric test revealed that there were significant differences between cattle herd size hot spot and cold spot group distributions (*Chi-Sq = 56.6, df (4), p <.001*)(Figure 2.6). Between classification groups, the majority of comparisons were statistically insignificant (Bonferroni adjusted), other than when comparing the distributions of municipalities that fell under 'Very hot' and 'Very cold' cattle groups (Dunn's test statistic = 7.402, *p <.001*), and again between 'Neutral' and 'Very cold' (Test statistic = -4.916, *p <.001*).

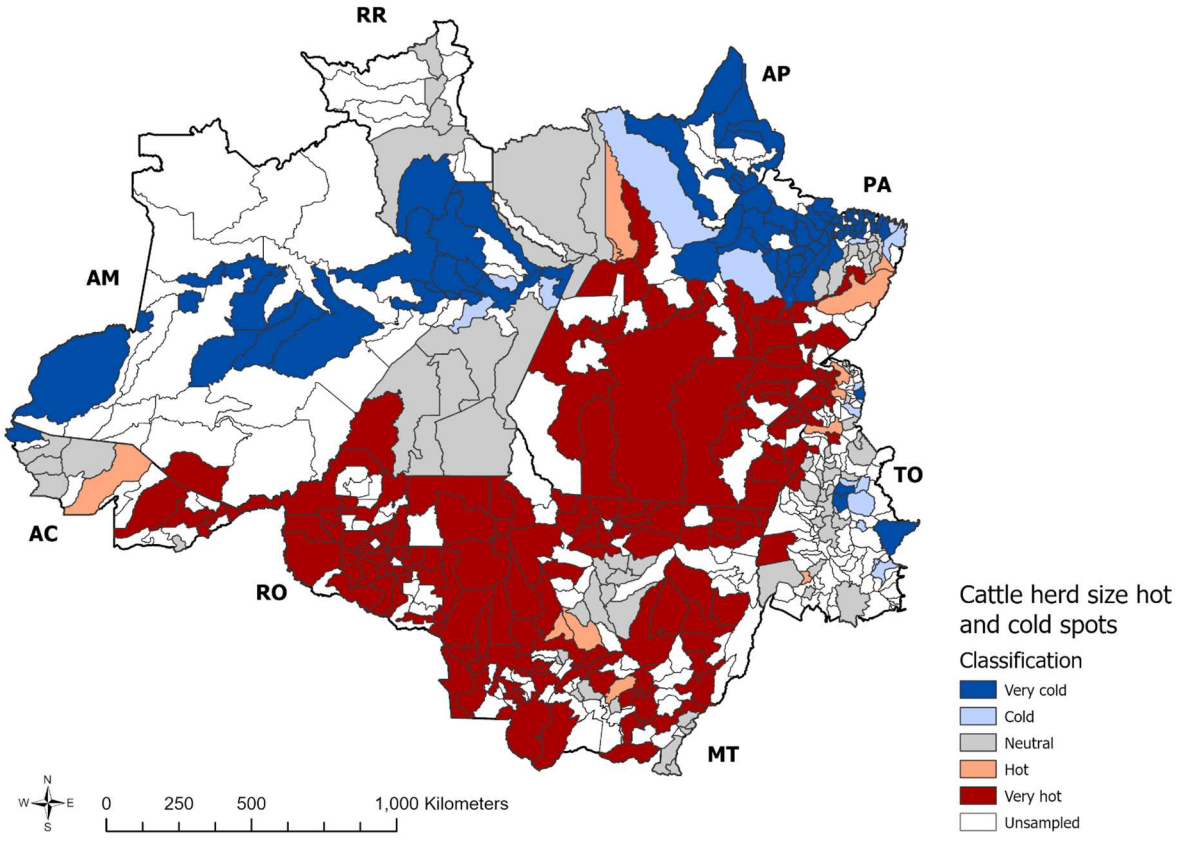


Figure 2.6. Spatial hotspots and cold spots of cattle herd sizes across 335 municipalities in eight sampled Amazonian states. *Identified from Getis-Ord tests. Corresponding State Acronyms are shown adjacent to the state highlighted by the thicker black line (e.g. AM for Amazonas). Blank municipalities (White - shown as 'Unsampled' in Legend) represent municipalities with missing data, or insufficient data collected for our response variable of interest (<8 songs, Sertanejo country music).*

The Kruskal-Wallis non-parametric test revealed that there were significant differences between cattle herd size hot spot and cold spot group distributions (*Chi-Sq = 56.6, df (4), p <0.001*) (Figure 2.7). Between classification groups, the majority of comparisons were statistically insignificant (Bonferroni adjusted), other than when comparing the distributions of municipalities that fell under 'Very hot' and 'Very cold' cattle groups (*Dunn's test statistic = 7.402, p < 0.001*), and again between 'Neutral' (or 'Insignificant' in Figure 1.6) and 'Very cold' (Test statistic = -4.916, *p < 0.001*).

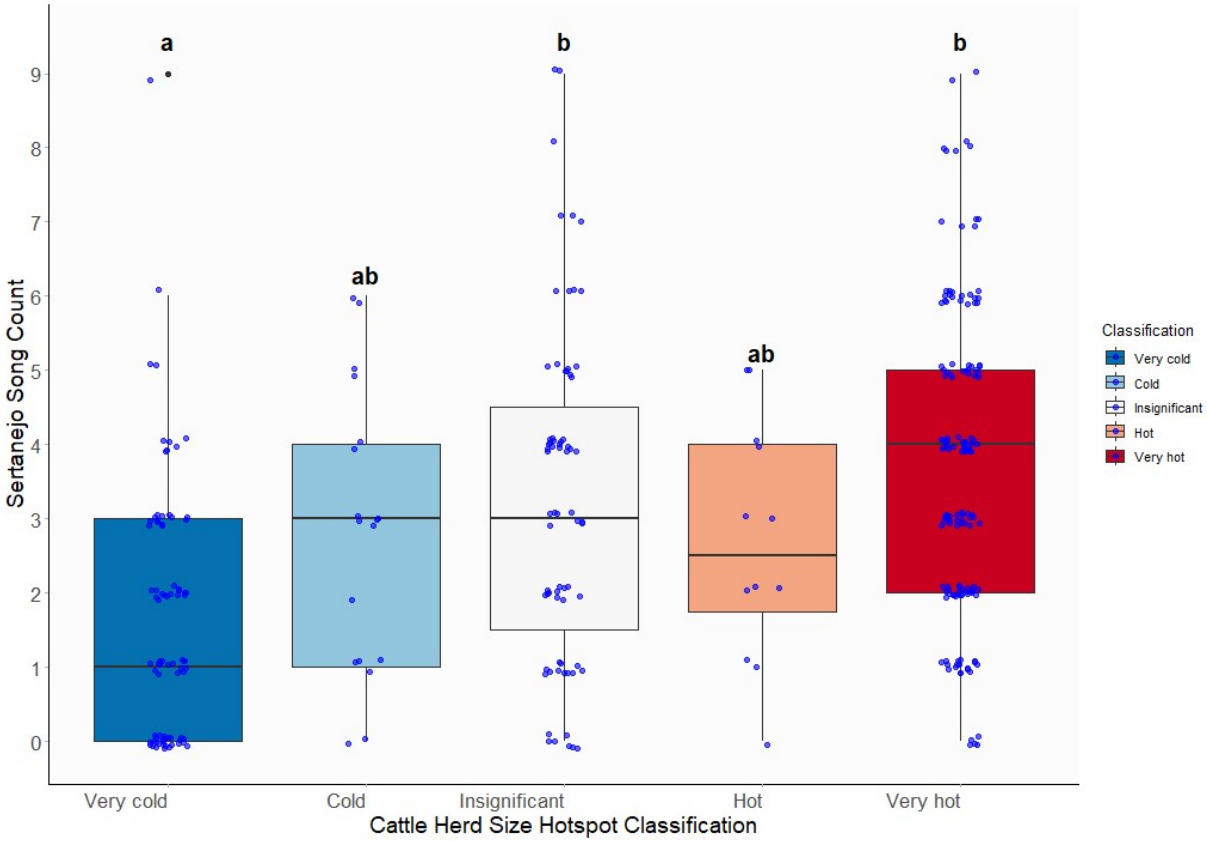


Figure 2.7. Boxplot of Sertanejo country music song counts, separated by cattle (2019, Log+1 head of cattle) hotspot categories. *Overlaid are raw datapoints (using Gi statistics and p-values (Bonferroni correction) to determine classifications). Lettering above each box and whisker shows in group differences following Kruskal-Wallis and then Dunn Test to test intra-group distribution differences. Classification groups are determined to have insignificant differences unless the letter above the corresponding plot differs (e.g. a ≠ b when group distributions are significantly different, or p <0.05, Bonferroni adjusted).*

Statistical modeling:

For the cattle-only model (Model #1), which accounted for uneven total song counts across municipalities, cattle herd size (log transformed) was positively associated with Sertanejo song count. A one unit increase in the log cattle herd size was associated with a 13.9% increase in Sertanejo song counts (IRR = 1.14, 95% CI: 1.09 - 1.19, $p < 0.001$), while doubling herd sizes is associated with a 9.4% increase in Sertanejo song counts. When controlling for metropolitan proximity and out-of-state migrant number (model #2), a one-unit increase in log cattle herd size (2019) was associated with a 9.7% increase in Sertanejo song counts (IRR = 1.10, 95% CI: 1.05–1.15, $p < 0.001$). In other words, doubling herd size is associated with a 6.7% increase in Sertanejo song counts. Distance from large urban centres was also positively associated with Sertanejo song counts: a one-unit increase in log distance was associated with a 9.6% increase in counts (IRR = 1.14, 95% CI: 1.04–1.25, $p < 0.01$). Doubling the distance to a large municipal capital was associated with a 10.6% increase in Sertanejo song counts. Finally, migrant numbers were positively associated with Sertanejo song counts. Each additional migrant per 100 residents was associated with a ~1% increase in Sertanejo song counts (IRR = 1.01, 95% CI: 1.00–1.02, $p < 0.001$). In this control model, when all predictor variables are held at their mean value, the expected count of Sertanejo songs is about 3 (2.9, CI: = 2.69 - 3.12).

Table 2.4. Model results for GLM Negative Binomial Control Model (Model #2). Coefficient estimates with standard errors, Z, p-values of significance, IRR and corresponding 95% confidence intervals all reported for each covariate, with Intercept (Sertnejo song count, response variable) in top row.

Variable	**Coefficient**	**SE**	**Z**	***p-value***	**IRR**	**95% CI's**
Sertanejo song count	-3.988	0.559	-7.13	*<0.001***	0.019	0.006 - 0.055
Cattle herd 2019 (log)	0.093	0.021	4.38	*<0.001***	1.10	1.05 - 1.14
Migrants per 100 residents	0.01	0.003	3.54	*<0.001***	1.00	1.00 - 1.02
Distance to nearest	0.132	0.047	2.78	*<0.01***	1.04	1.04 - 1.25

municipal capital of 100k inhabitants (log)						

When including a spatial lag covariate (spatial autocorrelation term based on the number of Sertanejo observations per municipality), the effect of cattle herd size was still statistically significant ($p < 0.05$), where a one unit increase in the (log of) cattle herd was associated with a 5.2% increase in the Sertanejo song count (Table 2.5), and doubling herd size would result in a 3.58% increase in Sertanejo song count. The number of migrants per municipality was still significant in the spatial model ($p<0.05$), where an additional migrant per 100 citizens was associated with a 0.7% increase in Sertanejo song counts. Finally, a one unit increase in the distance from large urban centres was associated with an 8.6% increase in Sertanejo song count, however the effect becomes weakly significant in the spatial model *($p = 0.079$)*.

The spatial model (Model #3) confirmed the strong spatial dependence of the Sertanejo song count per municipality (as reported in Figure 2.4), where a one unit increase in the spatially lagged independent variable is associated with a 15.3% increase in Sertanejo song count, and this relationship was highly significant ($p < 0.001$). The spatial model confirmed there was a spatial basis (i.e. non-independence at municipality scale) to the Sertanejo song count data which was properly accounted for in this model (*Moran's I* on spatial model residuals = -0.056, $p = 0.949$). Ultimately, Model #3 indicated that larger cattle herds were positively associated with Sertanejo song counts, even when controlling for the impact of migration, remoteness from larger cities, and importantly, spatial proximity to other municipalities with higher Sertanejo song counts (Table 2.4).

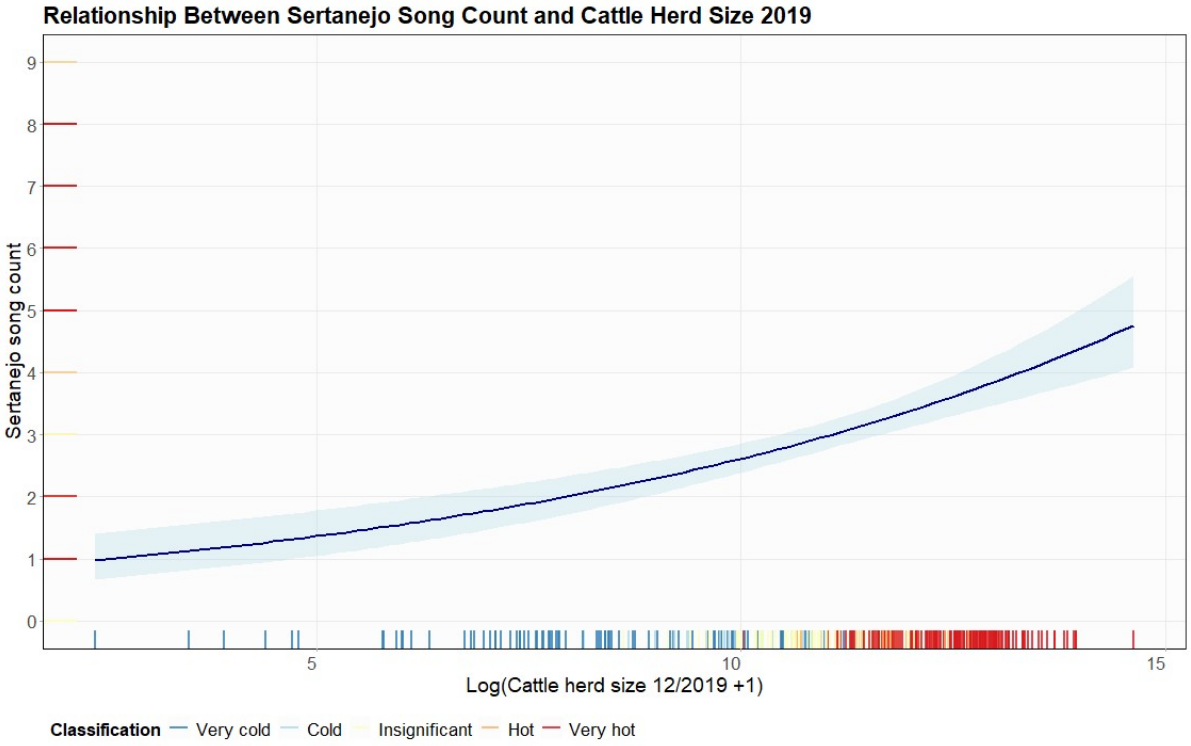


Figure 2.8. Predicted relationship between municipal cattle herd size (log-transformed) and the number of Sertanejo songs observed on local radio, with 95% confidence intervals. *The shaded ribbon represents the uncertainty around the predicted values from a negative binomial generalised linear model, while the solid line shows the model's fitted trend. Rug marks along the x-axis indicate individual municipalities, colored by cattle-herd classification (diverging palette, dark red = high, dark blue = low). This visualization highlights that Sertanejo popularity increases with larger cattle herds, while also showing the distribution of observed data across classification levels.*

Table 2.5. Model results for GLM Negative Binomial Spatial Autocorrelation Model (Model #3). Coefficient estimates with standard errors, Z, p-values of significance, IRR and corresponding 95% confidence intervals all reported for each covariate, with Intercept (Sertnejo song count, response variable) in top row.

Variable	**Coefficient**	**SE**	**Z**	***p-value***	**IRR**	**95% CI's**
Sertanejo song count	-3.314	0.556	-5.96	*<0.001***	0.036	0.01 - 0.11
Cattle herd 2019 (log)	0.051	0.022	2.26	*0.024**	1.05	1.01 - 1.10

Migrants per 100 residents	0.007	0.003	2.36	*0.018**	1.01	1.00 - 1.01
Distance to nearest municipal capital of 100k inhabitants (log)	0.082	0.047	1.76	*0.079*	1.09	0.99 - 1.19
Spatial Lag	0.142	0.030	4.67	*< 0.001***	1.15	1.08 - 1.23

When comparing the three models against one another, each iterative model provided significant improvements on the previous model (Table 2.6). The control model included covariates on the log of cattle herd size in 2019, the log of average distance to metropolitan cities, and migrants per 100 municipal citizens, which represented a significant improvement in the model fit ($LR = 20.82, p < 0.001$). The spatial model, which also included the spatial autocorrelation term in addition to all other covariates in the control model, in turn provided a significant improvement in model fit over the control model ($LR = 20.49, p < 0.001$).

Table 2.6. Reporting of ANOVA tests which compare a the reduced model (Sertanejo count x cattle 2019 (log) to model 2 (which adds further covariates of distance to nearest urban centre (minimum 100k inhabitants) and Total Migrants per 100 citizens of the Municipality, and then model 2 to model 3 (adding a further variable to account for spatial autocorrelation using a spatial lag). All models are GLM using a negative binomial error distribution.

Model	**Predictor Variables**	**df**	**2x Log Likelihood**	**Test**	**LR Statistic**	**Pr (Chi)**
#1. (Simple model)	Cattle herd size 2019 (Log)	332	-1377.889	-	-	-
#2. Including covariates	Cattle herd size 2019 (Log); Distance to Nearest Large Municipal	330	-1357.065	#1 vs #2	20.82440	*< 0.001***

	Capital of 100k inhabitants (Log); Migrants per 100 Citizens					
#3. Spatial model	Cattle herd size 2019 (Log); Distance to Nearest Large Municipal Capital of 100k inhabitants (Log); Migrants per 100 Citizens; Spatial Lag	329	-1336.573	#2 vs #3	20.491357	*<0.001***

In summary, Sertanejo song counts are positively associated with larger cattle herd sizes, which demonstrated significant overlap in terms of spatial distribution (see Figure 2.4, Figure 2.6, Figure 2.7 & Figure 2.8). This was still true when controlling for relative distances from large municipal capitals (of 100k inhabitants or more), and larger proportions of migrants living in the municipality. Importantly, even when controlling for the spatial dependency of Sertanejo song counts in municipalities, cattle herd size continued to demonstrate a significant effect. Finally, this spatial model (Model #3) properly accounted for the spatial autocorrelation initially found in model residuals in both Models #1 and #2, and represented a significantly better statistical fit, proving to be the best performing model of all presented in this section.

2.4 Discussion

We undertook the first large-scale assessment of spatial variation in cultural expression in Amazônia and found that local preferences for Brazilian country music (*Sertanejo*) were widespread but strongest in municipalities with larger cattle herds. To our knowledge, this is the first study in the world to quantitatively link musical preferences with land-use patterns at a regional scale, demonstrating the potential of cultural indicators as a lens for understanding environmental change. Sertanejo music reinforces a cultural narrative of prosperity and tradition linked to cattle-ranching yet we found it was prevalent even in highly forested areas, potentially indicating the diffusion of so-called cattle culture across the region. Culture is an

often overlooked element of tropical land-use change and to our knowledge has hitherto only been studied using ethnographic methods at small spatial scales (e.g. Hoelle, 2011, 2014, 2015, 2018), partly because a method to quantify culture at the same spatial scales as environmental data is yet to be popularised (le Polain de Waroux *et al.,* 2021). Our findings support previous studies in anthropology and human geography that highlight how culture has complex relationships with landscapes and land-use change, including in relation to cattle ranching, the leading driver of deforestation in Amazônia. We found that, although Sertanejo music was not significantly related with recent deforestation patterns it was significantly more popular in more deforested municipalities. Instead, we found Sertanejo to be strongly associated with larger cattle herd sizes at the municipal-level, a result that was robust to the impact of migration, remoteness from larger cities, and importantly, spatial proximity to other municipalities to other municipalities where Sertanejo was also popular. Taken together, these results may indicate that Sertanejo is a strong cultural marker of cattle-led frontier advance, becoming embedded in municipalities with even relatively modest cattle herd sizes, displacing other popular musical genres in the process.

2.4.1 Linking cattle ranching and the prevalence of Sertanejo music on local radio stations

We found that Sertanejo was more popular in municipalities with larger cattle herds, a finding that was robust to controlling for human in-migration and geographic context. These findings are congruent with the ethnographic literature that this study draws inspiration from, but this is the first study to have demonstrated the presence of cattle culture at large spatial scales. Sertanejo music was prevalent in all but the 'coldest' cattle coldspots – spatial groupings of municipalities with very few cattle and where Sertanejo accounted for only one-in-ten radio songs (see Figures 2.4 and 2.6). Hoelle (2011, 2014, 2015) argued that cultural preferences at a late-stage deforestation frontier in western Amazônia are strongly associated with cattle. Specifically, Hoelle observed that many people living in Acre state now express cultural norms associated not with forests and their biodiversity but instead with an idealised cattle-centric country lifestyle through things like Sertanejo music and rodeos. Hoelle (2018) went on to suggest that, as the leading driver of deforestation, expanding cattle herds (and the cultural preferences associated with raising cattle) may be associated with the advance of

deforestation frontiers if populations become steadily more favourable towards converting forests into pasture. Our empirical findings from 335 municipalities in seven Amazonian states support that proposition. This finding highlights an important aspect that has previously been theorised in other areas of sustainability science literature; cultural change can be as a response to outside phenomena, group composition change, or internal challenges (Kendal and Raymond, 2019).

Our results suggest that cattle-ranching is associated with the increasing local popularity of Sertanejo music, albeit we cannot determine causality using our evidence. Perhaps not coincidentally, growth in the cattle sector in the Brazilian Amazon is considered to be primarily driven by the growing domestic market for beef which is primarily in the South and South-East of Brazil (Haddad *et al.*, 2024), the same region where the roots of Sertanejo music originate (Oliven, 2008). We contend that rather than being distinct co-occurring phenomena, these changes are linked to a broader way of seeing the world that originates from outside of the Amazon (Hoelle, 2011; Anderson *et al.*, 2022), beginning with the economic and political enablement of deforestation for pasture expansion (Skidmore *et al.*, 2021). Consequently, the transformation or displacement of traditional Amazonian cultural features (such as folkloric music) seemingly occurs while Sertanejo becomes more popular, which is facilitated by the growth of cattle herds in the process of agricultural frontier advancement. Ultimately, it remains to be seen how the impact of the proliferation of Sertanejo popularity will and can impact other cultural practices (and potentially environmental outcomes) in Amazônia. For instance, is Sertanejo prevalence associated with the rise in popularity of other aspects of cattle culture, such as wearing *Cauboi* clothing, and does this contend with traditional forest cultures, or can these cultural identities coexist as deforestation frontiers advance? Moreover, is the subsequent cultural change related mainly to in-migration and population turnover, or do the locally born population also experience cultural shifts?

2.4.2 Sertanejo popularity reflects historical forest loss, not recent deforestation

We found that Sertanejo music on local radio stations was less common in municipalities that retain higher forest cover. However, we found no clear relationship between Sertanejo and recent or cumulative deforestation across municipalities in this study. Taken with our results

that showed cattle herd sizes - which are strongly negatively associated with forest cover and positively associated with deforestation - and Sertanejo to be strongly linked, this may indicate that cattle, rather than forest alone, may better explain variation in Sertanejo prevalence across Amazonian municipalities. Sertanejo is a well-recognized cultural marker of cattle culture (Hoelle, 2014, 2015). Interestingly, our results may enrich understanding of the dynamics of social-ecological system change in the context of farm-forest frontiers of the Brazilian Amazon. Hoelle (2011) presented the initial idea that the influx of cattle and in-migration to Amazônia are accompanied by positive cultural constructions associated with cattle. These cultural constructions are linked to cultural values that privilege prosperity and hard work, and devalue forests (Hoelle, 2018). Gomes *et al*., (2012) discuss similar livelihoods and land-use transitions taking place, reinforcing how increased economic security is a primary driver of smallholder cattle ownership in Amazônia, but affects how people who had previously identified with extractivist activities associated with traditional identities (such as rubber tapping) see themselves and their surroundings. Former rubber-tappers clearing a few hectares of forest to raise a handful of cattle is, in land-use terms, very minimal compared to what large scale cattle ranchers have cleared and continue to clear. However, the transition from forest extractivism to small-scale cattle rearing may be accompanied by new views on a way of life and production in rural landscapes, rather than environmental destruction itself (Kohler *et al.*, 2011). Despite the vastly different geographical scales that large scale cattle ranchers operate on, in both cases, forest must be cleared, or land that has already been cleared needs to be made productive, which is a central aspect of the cultural values associated with cattle (Hoelle, 2018). This underscores a more pernicious theme of social value change in relation to sustainability (Kendal & Raymond, 2019). Values for nature have been hypothesized to have transformative potential within sustainability science and related disciplines, with alternative worldviews and more relational aspects being cited as drivers of pro-sustainability attitudes and beliefs in policymaking (Himes *et al.*, 2024). Yet, positive cultural constructions and strong personal values can also be formed in connection to *un*sustainable practices that may later become barriers to conservation (Hoelle, Gould and Tauro, 2022). Moreover, the development of pro-cattle values in regions earmarked for tropical forest conservation may be exceedingly difficult to detect, because of the difficulty and complexity of accurately measuring cultural values (Caldas *et al.*, 2015; le Polain de Waroux *et al.*, 2021).

2.4.3 Sertanejo popularity is associated with declining cultural (musical) diversity

We found the popularity of Sertanejo to be incredibly widespread, with the impact of the genre's popularity spreading across municipal borders (as confirmed by our spatial models (Table 2.5); see Sertanejo hotspots in Figure 2.3). This may be unsurprising, given that Sertanejo is the most popular form of music in Brazil today (Martins and Teixeira, 2023). Notably though, Sertanejo play time on local radio stations was associated with declining musical diversity. The emergence as the new genre of choice across Amazônia (at least when considering the number of municipalities in which it is popular, as opposed to measuring the total number of listeners, which is likely to be skewed towards the musical preferences of metropolitan populations in Belém, Manaus and elsewhere) is recent. Traditional Amazonian musical styles such as Brega and Carimbó draw from multiple (both external and domestic) influences (Lamen, 2013), and are musically and rhythmically distinct from other, more internationally recognisable Brazilian musical genres (e.g. Samba, MPB). The dominance of Sertanejo and its apparent negative impact on musical diversity evidenced in this study generates interesting parallels with research showing impacts of biocultural homogenization for both ecosystem health and social welfare (Hanaček and Rodríguez-Labajos, 2018). Landscape simplification, such as converting tropical forest to pasture, can result in the loss of complex natural processes but may also come with additional human consequences, such as the simplification of previously diverse values and ways of living (Riechers *et al.*, 2020). Importantly, the relative dominance of Sertanejo may encourage similar social consequences through the negation of musical diversity associated with traditional identities (for example, through suppression of traditional musical styles in a municipality's key public cultural events). Similar to Gomes *et al.'s* (2012) finding that traditional identities are often intertwined with livelihood strategies and cultural expression rooted in forest-based practices in Acre state), we show that contrasting expressions associated with cattle are negatively related to landscape (forest cover) and cultural diversity (music).

In addition to Sertanejo, Gospel music was the second most popular genre in terms of overall play-time across all municipalities (Table 2.1), highlighting the growing influence of religion as a cultural force in Amazônia (Killeen, 2025). Interestingly, Gospel play time was also negatively associated with musical diversity (Supplementary Figure 2.3). This has tangible

environmental implications, as evangelical churches have become increasingly active in Brazilian politics, and are typically aligned with the so-called "*Boi, Bíblia e Balas"* (Beef, Bible, and Bullets) bloc, which actively supports the expansion of agricultural frontiers (Killeen, 2025). Although, this result should also be interpreted cautiously, because recent evidence has also documented the role of religious groups in pro-environmental movements (Smith and Veldman, 2020; Ives *et al.*, 2024; Koehrsen and Ives, 2025).

An important consideration for this study that has yet to be discussed is the political nature of radio playtime. The radio has been thought of as a political instrument for more than 80 years (Saerchinger, 1938), with radio playlists, advertisements and messaging being dictated by ownership (Cowling, 2005). In Brazil, municipal politicians have repeatedly gained government approval to exert control over daily programming of local radio stations closer to the time of local elections (Boas and Hidalgo, 2011), demonstrating the political nature of radio playtime in our study context. This study did not examine the ownership of local radio stations included in collected data, but in the case of many rural Amazonian stations, the groups most likely to own local radio are those with the capital to do so, such as ranchers or other social groups with large landholdings and access to credit (Hoelle, 2011). The connections between large scale agribusiness and right-wing political figures in Brazil is well documented (Phillips, 2019; de Area Leão Pereira *et al.*, 2020; Fearnside and Filho, 2025), and the links between Sertanejo and cattle ranching have been explored in some depth throughout this chapter. It is feasible that in municipalities where Sertanejo was played the most in this study that this is the result of ownership of radio stations by cattle ranchers, or at the very least, social groups that prefer Sertanejo over local musical genres, in rural Amazonia. This raises important questions about the relative power of social groups to control popular cultural dissemination in rural Amazonia. A prominent example of this would be the more than 35 investigations into potential corrupt deals between town mayors and local agribusiness executives conducted in 2022 because Sertanejo megastars (such as Gusttavo Lima) had received R$800,000 (over £100,000) per show to play concerts to a municipal population of approximately 8,000 people (Pavão, 2022).Although we have discussed the negative association between higher forest cover and Sertanejo popularity, in addition to the takeover effect that Sertanejo seems to demonstrate for other musical genres, important questions (that are beyond the remit of this study) remain. For instance, future research might investigate whether people in more densely forested municipalities culturally

resist Sertanejo or other cultural norms associated with cattle culture. Further, future research may attempt to understand whether the spread of cattle culture directly linked to the simplification of landscapes from forested to pasture, and potentially, what the resulting impact on environmental attitudes, beliefs, or values might be.

2.4.4 Study Limitations

This research however is subject to a number of limitations. The first is that using the prevalence of different musical genres is a relatively simplistic proxy for cultural variation. Although music plays a key role in individual and collective cultural expression (Bennett, 1999), it would be impossible to represent culture in its entirety through these means, which would instead require more in-depth qualitative work by musicologists and anthropologists. Second, the time period of testing for musical preferences (8 months between February and September 2023), represents a short time period that may or may not be representative of local radio playlists. Future repetition of this method would be necessary in order to verify that the relative playtime of all genres is representative of sampled radio stations. Thirdly, the degree to which municipal radio stations can be stated to represent a population's musical tastes are debatable and warrant further study into cultural variation within municipalities and also research to understand the extent to which different sub-populations listen to local radio in the present day. To control for this particular assumption, we cross-referenced our results with survey data collected by the study PI during remote fieldwork in 2024, which revealed that almost two thirds of people interviewed across four diverse Amazonian municipalities in both urban and rural areas listened to the local or municipal radio 'at least sometimes' (65%). Importantly, 36% of survey respondents listened to the radio 'Often' or 'All the time' (Supplementary Table 2.2).

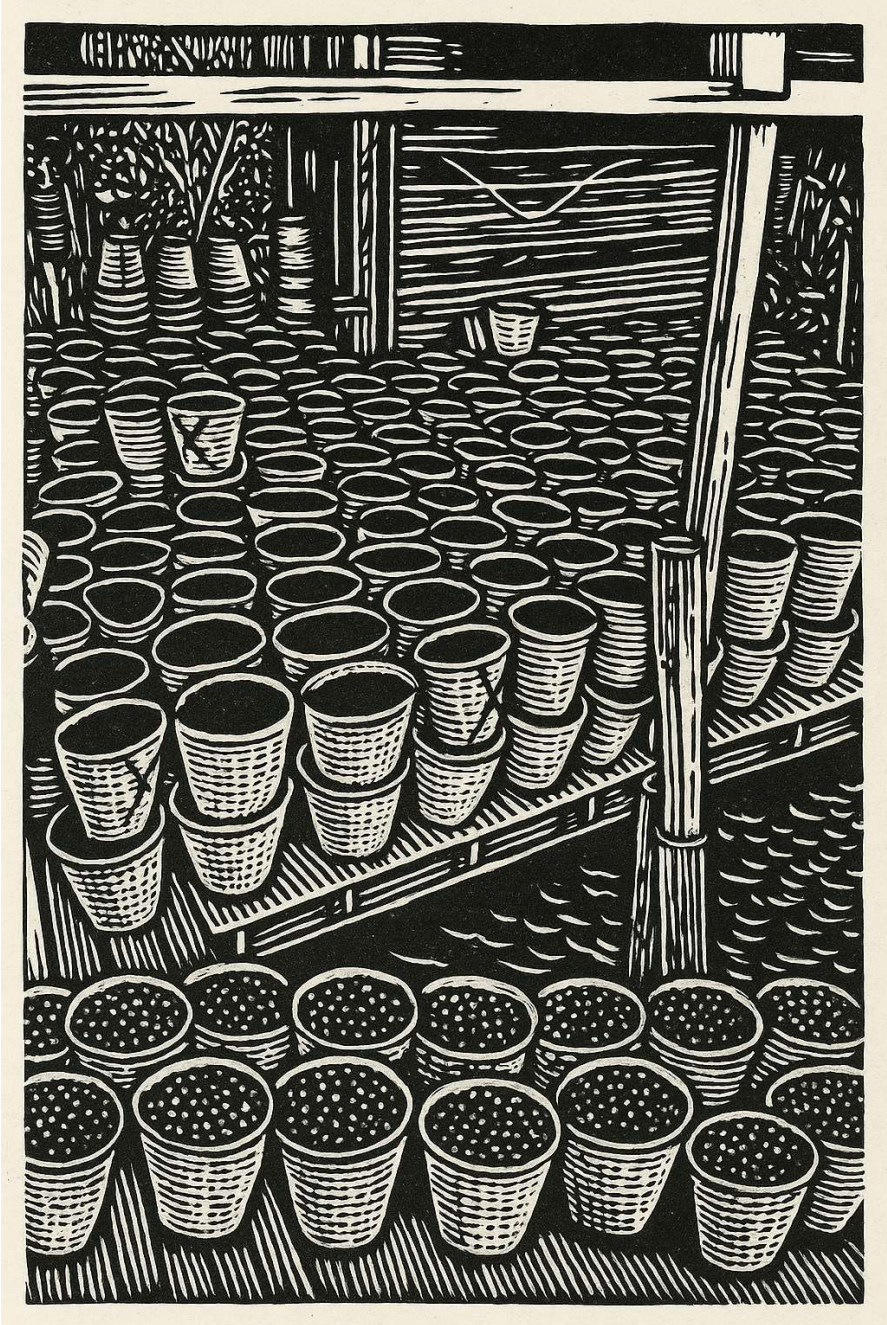
Another potential bias is that perhaps cattle-ranching elites – where they exist — may exert an outsized impact on local radio stations and other forms of cultural expression (e.g. line-ups in cultural events) due to their financial patronage and political power. A further limitation of this study is the availability of municipal radio stations through our chosen method (www.radios.com.br). This limited the number of municipalities that were available to be included in both our dataset (where 0 songs were collected) and later in final data analysis (40 municipalities removed for inadequate sampling (<8 songs)), and additionally meant that we

generally found that municipalities with a higher number of radio stations had more diverse listening preferences (albeit it is plausible that larger cities tend to have more radio stations *and* more diverse musical preferences). Finally, the use of Shazam (albeit with post-validation by an Amazonian musical expert) to identify musical genres means that our measures of musical diversity under-estimate the prevalence of unique Amazonian genres. Although Shazam is particularly adept at identifying the genre of most Western musical styles in short snippets, we found that at times it struggled to identify more nuanced versions of local music. This is especially important in Amazônia because of the diversity of Amazonian genres such as Brega (a type of ballad/electronic dance music) which would were instead classified intro broader genres such as Dance.

2.5 Conclusion

Culture is considered difficult to include in land-use science and policy mainly because it is difficult to quantify (le Polain Waroux *et al.*, 2021). We have begun to elucidate the complex relationships between land-use change and culture in the Brazilian Amazon. In this globally-important biome *and* complex social-ecological system home to 27.8 million people, competing visions of a desirable future – ranging from environmentalism and the bioeconomy based on sustainable use of natural resources, to autonomous indigenous cultures and cosmologies, to development based on industrialized agriculture and mega-projects – are playing out through political, economic and, we suggest, cultural contestation. Ultimately, this study helps us to improve our understanding of how cultural expression is linked to cattle, agricultural expansion and deforestation. We demonstrated that larger cattle herds were positively associated with the prevalence of Sertanejo on local radio stations, even when controlling for the impact of in-migration, remoteness from larger cities, and importantly, spatial proximity to other municipalities with higher prevalence of Sertanejo playtime. Cattle ranching is deeply entangled with culture in complex ways and can serve to push out other cultural norms (and potentially values) associated with traditional ways of living with and in forested landscapes – highly problematic for the paradigm of sustainable development in Amazônia. Any policy interventions aimed at changing land use decisions related to cattle would likely need to take into account these changing cultural norms, and draw upon strong forms of community engagement and involvement to retain incumbent cultural expression and values associated with traditional identities. Finally, future research might investigate

how cultural expression is challenged or changed as a result of landscape simplification, and how different forms of cultural expression are associated with environmental values, or nature connection as predictors for pro-environmental choices across forested and cattle-intensive landscapes.



Eu logo pude prever, parece que vai chover, parece que vai chover,

I could soon predict, it looks like it's going to rain, it looks like it's going to rain,

Depois que a chuva passar, vou cantar carimbó pra você,

After the rain passes, I will sing carimbó for you,

No meio do Pitiú, no meio do Pitiú

In the Middle of the Pitiú, In the Middle of the Pitiú…

(Dona Onete, 'No Meio do Pitiú', 2016)

Chapter 3: Cultural expression at Amazonian deforestation frontiers

Jordan O. Lafayette [1], Luke Parry [1], Christopher D. Ives [2], Jeffrey Hoelle [3] and Carlos Valério Aguiar Gomes [4], Gustavo Roberto Coelho [5], Paulo Rigo Gomes Santos [6], Maria Raimunda da Silva Nascimento [7], Antônia Paula Vasconcelos Leite [5]

[1]Lancaster Environment Centre, Lancaster University, Lancaster, UK

[2]School of Geography, University of Nottingham, Nottingham, UK

[3]Department of Anthropology, University of California, Santa Barbara, CA, USA

[4]Amazonian Institute of Family Agriculture, Federal University of Pará, Belém, Brazil

[5] Federal University of Amazonas, Manaus, Brazil

[6] Federal University of the South and South-East of Pará, São Félix do Xingu, Brazil

[7] Federal Institute of Pará, Paragominas, Brazil

Chapter Acknowledgements

I would like to sincerely thank the Amazonian Institute of Family Agriculture for hosting me as a research student, especially the postgraduate program coordinator, Profa. Dr. Monique Medeiros, and the head of department, Prof. Dr. Luis Mauro Santos Silva. I would also like to thank the many community health agents (ACS) and secretariats of Lábrea, Tefé, Paragominas, and São Félix do Xingu, without whom data collection would have been implausible. Finally, I would like to thank the multiple professionals at local environmental and research organisations, such as Marcikely Santos at ASPACS in Lábrea, Heloisa Pereira at the Mamirauá Institute in Tefé, and Celma de Oliveira at Imaflora in São Félix, who provided much needed support and practical guidance, aid and research bases for rural data collection.

Author contributions

All authors contributed to the conceptualisation or active collection of this research. J.O.L performed the research with the help of G.R.C, M.R.N., P.G.S., and P.V.L.

J.O.L then wrote the first manuscript draft. J.O.L., L.P. and C.D.I. edited the current manuscript, while J.H. and C.V.G. provided comments throughout.

Abstract

Cultural identities are fundamental to the livelihood strategies and land-uses of traditional forest-proximate people worldwide. Particular cultures can emerge and become dominant in particular places, or be displaced and therefore recede, through economic and environmental transitions in combination with human migration flows. Ethnographic research in an Amazonian farm-forest frontier demonstrates that 'cattle culture' can emerge in such contexts experiencing rapid socio-ecological change including colonization of loggers, colonist farmers and cattle ranchers, and the dispossession of traditional forest-dwellers. Cattle culture's rise may cause Amazonian populations to become less attached to forests and, conversely, more favourable towards the expansion of pasture and cattle herds. However, it is unclear whether mainstream, dominant, cultural identities change across Amazonian deforestation frontiers, and if changes are restricted to rural people or extend to nearby urban populations. This study examines cultural markers of traditional Amazonian culture and cattle culture, and evaluates how these differ across deforestation frontiers and between rural and urban populations. We conducted structured surveys with 407 people residing in four municipalities of the Brazilian Amazon at different deforestation frontier stages (characterised by recent deforestation intensity and historical primary forest loss). Affiliation with markers of traditional Amazonian culture was lower in the intermediate and late frontier municipalities, whereas cattle culture markers were higher relative to pre- and early-frontier municipalities. Proximate urban and rural populations shared many cultural characteristics but differences were context-specific. For instance, urban residents in early frontier Lábrea identified with traditional Amazonian culture more strongly than their rural counterparts. In the highly-active cattle frontier of São Félix do Xingu rural respondents were strongly negative towards Amazonian culture and, perhaps unsurprisingly, identified strongly with cattle culture, more-so than did people in the local town. Interestingly, people's migration history did not explain overall differences in cultural expression. Nonetheless, people born in São Félix associated more strongly with cattle culture than in-migrants, and in-migrants to late-frontier Paragominas affiliated with cattle culture more than people born there. Consequently, we show that social-ecological context and migration flows are strongly linked

to variation in cultural identities, although we cannot determine whether cultural change is contributing to, or reflecting, landscape change; perhaps both.

3.1 Introduction

Amazonia is the most biodiverse ecosystem on earth (Ribas *et al.*, 2025), which also houses diverse forest-based cultural identities across the Basin (Schmink, 2011). Deforestation is a destructive form of land-use and land cover change (LULCC hereafter) that threatens both biodiversity and human livelihoods and cultures (Garnelo, Fearnside and Ferrante, 2023). The Brazilian Legal Amazon has endured decades of thousands of square kilometres of deforestation per year (Levy *et al.*, 2023). Despite some effective interventions reducing deforestation rates by 83% between 2004 and 2014 (INPE, 2016), deforestation increased since 2015, peaking in 2020 during the Presidency of Jair Bolsonaro and a related drop in enforcement actions (Silva-Junior et al., 2020). A widespread consequence of large-scale deforestation is the displacement of traditional rural populations, and the resulting loss or erosion of traditional landscape management practices (e.g. rubber-tapping within forests, and swidden agriculture in a forest-farm-fallow mosaic) that have facilitated the formation of rich and diverse cultural identities of peasant communities across Amazonia, such as rubber tapping (Schmink *et al.*, 2008).

The on-going, often violent, encroachment of illegal logging and cattle-ranching into forested landscapes threatens traditional Amazonian communities, including in relation to their livelihoods and cultural identities (Levers *et al.*, 2021). Importantly, natural landscapes and the resulting biodiversity that they support have been deliberately curated by indigenous populations (Heckenberger et al. 2007), with land-use practices being mediated by the dominant cultural lens in which they exist (Caldas et al. 2015). Beyond Pre-Colombian and contemporary indigenous societies, Amazonian peasants and other rural actors continue to shape forest landscapes including by planting useful species of tree (e.g., Brazil nuts; Brouwer *et al.*, 2021) and palms (e.g. açai, but see Freitas *et al.*, 2015). *Caboclos* for example, are peasants of mixed Indigenous, African and European descent, who have deep roots in Amazonia's colonial history (Nugent, 1997). Amazonian peasantry are recognized for developing complex and adaptive livelihoods (Schmink, 2003; Adams *et al.*, 2009) that have traditionally involved seasonally-dependent combination of reliance on small agricultural plots (primarily to grow *manioc* or cassava), fishing and other aquatic harvesting

techniques from Amazonian rivers and lakes, and the harvesting of non-timber products (including plants and game animals) from forests (Nugent, 2017; Fraser *et al.*, 2018).

Many peasant cultures are embedded within extractive reserves, sustainable-use protected areas, or these cultural identities have influenced community mobilization and bottom-up demands for territorial recognition and reserve creation (e.g. Aleixo and APADRIT, 2011). Within sustainable use reserves, participatory governance regimes permit subsistence activities such as small-scale agriculture, fishing, hunting, and the harvest of non-timber forest products (Gomes *et al.*, 2018; Pacheco and Gomes, 2023). These management models have continually demonstrated that forests can support the lives and dignity of rural people and prevent deforestation and conserve biodiversity (Herrera, Pfaff and Robalino, 2019; Gonçalves-Souza *et al.*, 2021). However, should the loss of forest habitats in the Amazon continue at current rates, this poses critical concerns for both the loss of biodiversity, important ecosystem services and traditional Amazonian peasant cultures across Amazonia.

The study of LULCC in the Brazilian Amazon has mostly analysed the effects of a range of economic, social and political drivers on deforestation at the scale of property and municipality, whilst accounting for macro-scale influences ranging from policy change to fiscal conditions (Garrett *et al.*, 2017; Hoelle, 2018). However, recent work has seen more calls to include culture. For instance, Hodel *et al.* (2024) identify that the literature addressing culture's role in LULCC suggests that culture~land-use relationships are driven by a mixture of norms, practices, values and symbolic meanings that people assign to landscapes based on the cultural context that they live, work, and interact in. Caldas *et al.* (2015) identify, however, that the uncertain nature of how to quantify, limits how effectively culture can be integrated in the study of LULCC. Following work, such as le Polain de Waroux *et al.* (2021) then attempted to outline how culture~land-use relationships might be broached, before environmental anthropology (Hoelle, 2018) attempted to quantify cultural values associated with land-use in Western Amazonia. In other tropical countries, the role of culture in LULCC has often been examined by comparing differences in land-use strategies between Indigenous and colonist mixed-heritage farmers (Gray *et al.*, 2008), or the real-world tensions between local conservation policy and agricultural practices (Scales, 2012). While the potential role of culture in land-use has been recognised for quite some time (Iverson Nassauer, 1995; Lambin, Geist and Lepers, 2003; Plumwood, 2006), the integration of culture into land-use

models in Amazonia (and across the tropics) has lagged behind, in part because the more tangible aspects of culture, such as *cultural expression*, have not been yet quantified.

We understand culture to be a system of meanings that is shared and passed down by groups of people, and used as a lens to interpret the world and guide behaviours (Geertz, 1973). Human cultures can be directly tethered to geographic locations or landscapes (Iverson Nassauer, 1995; Kottak, 1999). Yet, culture has seldom been included in investigations of more destructive land-use practices, such as deforestation (Hoelle, 2018), largely because it remains difficult to quantify and therefore is not easily integrated with quantitative analyses of biophysical change. Consequently, cultural factors have been difficult to integrate into applied land-use research and decision-making (le Polain de Waroux *et al.*, 2021). Nonetheless, if research into, and conservation actions around, land-use practices focus only on economic and political dimensions, environmentalists and others risk overlooking a critical element of landscape change. Relevant to this study are the land-use practices of a range of social actors, ranging from smallholders, colonists in agrarian reform settlements, to large-scale cattle ranchers and powerful land-owning elites. In all cases, decisions over any subsistence production, forest dependencies or clearance, and whether and how to raise cattle, are influenced by cultural orientations and value systems (Caldas *et al.*, 2015). While broader systems of industrialisation, capitalism, and imperialism undoubtedly form an important backdrop for Amazonian land-use, our focus in this study is on how locally understood cultural lenses shape the everyday choices of Amazonians - as producers, consumers, and citizens - which influence deforestation and land use change.

3.1.1 Traditional land uses support Amazonian biocultural diversity

Traditional peasant communities in the Brazilian Amazon have an extensive history of forest-dependent livelihoods and lifeways, and cultural identification with forests (Schmink *et al.*, 2008). Amazonian forest communities have long been out-of-sight or *invisible* – in the sense of not being seen or having their views and harms recognized or valued (Adams *et al.*, 2009) – and historically denied secure land tenure, which has made them vulnerable to dispossession by more powerful actors and interests, including the state (Fraser, 2018). Landscapes are imbued with culture (Wu, 2010, 2019), and can be regarded as cultural spaces (Plumwood, 2006). Although indigenous cultures are highly heterogeneous and have helped

to shape the Amazon into what Heckenberger *et al.* (2007) famously described as cultural landscapes, they are distinct from Brazilian Amazonian peasant cultures, which are also informed by forest proximity and dependence (Schmink, 2003). Amazonian peasant culture went unstudied by anthropologists until Nugent's (1993) pioneering work, yet peasant societies – and not indigenous populations – constitute the majority of the rural population across the Amazon Basin. For instance, Parry *et al*. (Parry *et al.*, 2025) estimate the total rural population in the Brazilian Amazon is 9.11 million people, of which only 404,950 live in Indigenous Lands (albeit some indigenous people live outside of these territories). The traditional peasant population size would be hard to define precisely but would certainly be in the millions. Consequently, it is plausible that in most cases deforestation frontiers – and the violent waves of illegal logging, land speculation, and cattle-ranching that accompany them – are pushing into forested landscapes inhabited by peasant communities.

We define 'Amazonian peasant cultures' as the diverse lifeways and social formations of smallholder farmers, extractivist, and rural labourers in the Brazilian Amazon, whose livelihoods are historically shaped by a blend of subsistence production, participation in regional and local markets, and complex relations with state, capital, and nature (Hecht and Cockburn, 1989). Far from static, these cultures are not simply traditional remnants, but are dynamic and adaptive systems that emerge from long-standing interactions between traditional inhabitants of forested landscapes and continue to adapt in response to the increasing urbanisation of the Amazon biome (Browder and Godfrey, 1997). Traditional cultures are typically formed by and related to forest dependency, including but not limited to fishing, hunting, forest product extraction (e.g. rubber, Brazil nuts), and in more recent years, small-scale cattle raising (Gomes, Vadjunec and Perz, 2012). This dependence has thus involved the development of new heritages, ways of living, and place-based collective identities (Cabana, 2011) (Figure 3.1). Amazonian peasant cultural identities are held by the majority of residents in the Brazilian Amazon and are therefore important in shaping dominant societal norms. Typically, as outlined above, these cultural norms are tied to sustainable land-use practices and forest management strategies (Gomes, Vadjunec and Perz, 2012; Pacheco and Gomes, 2023). However, these identities and practices are under threat from persistent encroachment of agricultural expansion (Seymour and Harris, 2019). This is problematic because the history of agricultural expansion has typically come with violent infringements on the rights and livelihoods of traditional local communities (Schmink and Wood, 1992; Little, 2001). Thus, sustained forest loss threatens more than ecological

functions, with the place-based peasant identities at risk of gradual erosion (Levers *et al.*, 2021). The symbiotic link between biodiversity and cultural practices, languages, and knowledge systems that constitute the biocultural diversity of the Brazilian Amazon are consistently being challenged (Hecht *et al.*, 2024). Importantly, the wider environmental and social impact of disruptive external forces that threaten this biocultural diversity is currently unclear (Otamendi-Urroz *et al.*, 2025). While these challenges may be smaller changes that require personal adjustments to livelihood strategies, such as the adoption of small-scale cattle ranching (Gomes, 2009; Gomes, Vadjunec and Perz, 2012), substantial challenges to the diverse lifeways that have characterised Amazonian peasant identities often come from external pressures for environmental resources, the most pernicious of which is agricultural expansion for cattle ranching (Araujo, Combes and Féres, 2019).

Figure 3.1. Examples of traditional daily practices that are formed and reinforced by a dependence of peasant societies on forests, rivers and lakes in the Brazilian Amazon. *These examples include fruit and nut harvesting (top left); largescale cultivation and consumption of açaí palm fruit (top right); frequent travel by Canoe between rural areas and urban centres, as well as between communities and to/from farmlands and hunting/fishing zones, typically (but not always) with an attached gasoline-powered motor (bottom left); and fishing as a key aspect of subsistence and livelihood support for riverine and urban communities across Amazonia (bottom right). Images*

generated above were designed by Freepik (2025) (https://www.freepik.com/), with the exception of top right, which was taken by the lead author (JOL) on rural fieldwork, 2022.

3.1.2 Cattle culture in Amazonia

Ethnographic research at a farm-forest frontier of the Brazilian Amazon shows that a novel cultural identity (at least in Amazonian terms), 'cattle culture', develops in regions that have undergone extensive forest loss (Hoelle, 2014). Cattle culture relates to a broader way of seeing the world that is framed by positive cultural constructions associated with cattle and pasture (Hoelle, 2015) (Figure 3.2). The diffusion of cattle culture is directly influenced by the influx of cattle, but the dissemination of the culture itself is also attributable to the in-migration of southern Brazilians into Amazonia (Fearnside, 2008; Hoelle, 2011). Cultural traditions based on the g*aúcho* cattle herder identity from southern Brazil, are transposed onto Amazonian landscapes (Oliven, 2000). Cattle culture is often expressed by scholars as a direct competitor to, or opposite of, forest-based culture in terms of livelihoods, land-uses and identities (Hoelle, 2011). However, cultural identities in the Amazon can be hybridized in response when peasants combine small-scale cattle-raising with their other livelihood strategies (Pereira, Simmons and Walker, 2016). This would imply that these identities and their associated cultures exist on a continuum, with a variety of other possible cultural expressions in between that depend on the nature of land-use that a person engages with (Milton, 1997). The influx of cattle can begin to substitute aspects of traditional Amazonian cultures, such as dominant clothing choices, musical preferences or food preferences (Hoelle, 2015). This may eventually lead to the displacement of traditional cultural identities in favour of cultural constructions associated with cattle (*cauboi* culture in Portuguese), which brings with it alternative worldviews, values and cultural norms around land-use and desirable landscapes (Hoelle, 2018).

Figure 3.2. The five themes of cattle culture (Hoelle, 2015, pp 149-150). *These themes are indicative of the values and behaviours that underlie cattle culture, and the positive sentiments associated with cattle raising. Importantly, these preferences for cattle raising are typically framed in opposition to the forest as a space for nature. In order, these themes relate to: 1) The perception or belief that raising cattle is the best way to use the land; 2) Ascribing positive social attributes to people or groups who raise cattle, especially compared to those who rely on forest extractivism; 3) Valorization of a cattle-based lifestyle through popular fashion and activities related to cattle; 4) Frequent consumption of beef or the belief in the positive social and symbolic meanings associated with it, especially in relation to other foods; and 5) A preference for raising cattle as a way to relate to and interact with nature, expressed through practices and a lifestyle that show human control of nature e.g. pasture over forest. Images generated above were designed by Freepik (2025) (https://www.freepik.com/).*

3.1.3 Political ecology of frontiers, ecological and cultural loss

Zycherman (2016) argued that agricultural frontier advance in Amazonia is causing the displacement of traditional Amazonian culture(s) with new cultural identities based on cattle-raising and soy farming. Agricultural frontier advance in Amazonia refers to the ongoing spatial expansion of agriculture and cattle ranching into previously forested or sparsely used lands (Ioris, 2018). Driven by deforestation, land clearing, and settlement processes, frontiers are shaped by migration, road building, and policies that incentivize land occupation. They are spaces where diverse peoples come together, often violently, to contest land uses and livelihoods (Thaler, 2017). Frontiers include not only the biophysical aspects of land-use

change, but also demographic, cultural, political, social, and economic transitions (Hecht and Cockburn, 1989). Frontiers are not simply about the domination and extraction of environmental resources, but also about more profound ideals of a desirable future for a place or region (Schmink and Wood, 1992). In contrast to the pro-developmentalist visions of the future which attempt to advance agricultural frontiers, traditional and indigenous populations have been living (relatively) sustainably from forests, both prior to the surge of cattle capitalism of the Amazon from the 1980s and in the present day in legally-recognized forest territories (Kröger, 2020). Proponents of the territory-based sustainability model – including indigenous peoples, rubber-tappers, and others – are deeply organized and committed, and have influenced environmental policy-making in Brazil (Hecht *et al.*, 2024). However, the abilities of forest peoples (or forest citizens) to actualize their rights are constrained by challenges including combination of statal neglect and under-funding, violent resource grabs by outsiders, climatic shocks and unfavourable access to markets and trade (Parry *et al.*, 2025). Importantly, the people that fall outside of these federally recognized territories face even more threats to the erosion of cultural connections they hold with forests.

The diffusion of cattle culture in Amazonia and its impact on traditional cultural identities has hitherto been studied only at small spatial-scales in Acre State, mainly using qualitative methods While the conceptualisation of cattle culture does make reference to alternative worldviews and values that privilege forest conservation (see Hoelle, 2015; 2018), it is currently less clear how cattle and forest-centric cultures may interact at deforestation frontiers. One approach to do this is to quantify aspects of cultural expression related to both traditional Amazonian and cattle cultures that measure cultural assimilation with both concepts. Within demography, other population-level trends in cultural change have been assessed: both Stewart *et al.* (2019) and Vieira *et al.* (2020) used Facebook API data to characterise the extent of migrants' affiliations with local populations through music and food preferences, respectively. In the Amazonian state of Acre, Brazil, anthropologist Jeff Hoelle (2018) undertook a structured survey to evaluate relative diversity in cultural values related to cattle among six social groups (rubber-tappers, colonists, ranchers, cowboys, policy makers, NGO workers) living and working in relatively late-stage deforestation frontier contexts. However, this study, while useful in outlining the specific cultural values associated with cattle and forests on a local scale, did not seek to understand cultural expression among ordinary people, or potential variance across deforestation frontiers.

To address these gaps, in Chapter Two of this thesis we used radio playtimes to characterise musical popularity (particularly for Sertanejo music, a staple of cattle culture) in relation to land-use at municipality level across the Brazilian Amazon. However, while this study provided insights into patterns of cultural expression at large spatial scales, research into other (non-musical) aspects of cattle culture, and how they interact with traditional Amazonian cultures at the population-level is needed. The aim of this study is to characterise cultural diversity through cultural expression in different frontier contexts, using grounded and theoretically-informed understandings of traditional peasant and cattle cultures in the Brazilian Amazon (drawing on work by Salisbury and Schmink, 2007; Gomes and Schmink, 2008; Schmink *et al.*, 2008; Hoelle, 2011, 2014, 2015; Schmink, 2011; Gomes, Vadjunec and Perz, 2012; Zycherman, 2016, among others). Moreover, we apply robust quantitative population surveys and targeted measures of these two cultures, thereby addressing key concerns about a lack of quantifiability of culture in relation to LULCC. This is done through the creation of a novel survey instrument that captures these unique needs more acutely than previous survey instruments might allow.

This study aims to quantify cultural expression related to traditional peasant Amazonian forest identities (herein we refer to this as traditional Amazonian culture) and cattle culture and evaluate changes across deforestation frontiers. We employed structured surveys in four distinct frontier contexts (characterised as pre, early, intermediate, late), considered as frontier *stages (using spatial variation in the present day as an analogue for temporal change and frontier advance, which limits our ability to determine causal relationships and instead can help identify associations)*. We assess levels of cultural expression through multiple aspects: musical listening habits, food preferences and consumption, clothing preferences, and cultural norms and pastimes. For each municipality we surveyed both urban and rural populations, aiming to answer the following questions:

1. Which distinct forms of expression related to traditional Amazonian culture and cattle culture are present in Amazonian populations?
2. How does the level of expression of traditional Amazonian culture and cattle culture change across deforestation frontiers?

3. Does the level of expression of traditional Amazonian culture and cattle culture differ between rural and urban populations?
4. At frontiers, do migrants from outside Amazonia have different cultural markers than people born in the Amazon?

3.2 Methods

3.2.1 Study Area

To ensure that our sample captured a diversity of frontier stages at both the meso-scale (municipalities with different levels of remaining forest cover, recent deforestation rates, and cattle herd size) and micro-scale (within each municipality we sampled from urban areas, and a diversity of rural locations with varying forest cover, pasture and agricultural land-uses), four Amazonian municipalities were selected based on some key criteria. First, all 772 municipalities in the Brazilian Legal Amazon were classified into quartiles of cumulative forest loss in 2023 as a proportion of original primary forest (from 1986, when Landsat-based remote sensing of deforestation and land-use change began). In order to select one municipality for fieldwork from each quartile, municipalities were shortlisted based on recent rate of deforestation from the widely respected MapBiomas research organization (https://brasil.mapbiomas.org/estatisticas/) and official government data on cattle herd size (IBGE, 2016). Final decisions were based on whether the project team had any contacts or ongoing project activities in those municipalities, to facilitate building a trusted network of local collaborators. This was important given the potentially sensitive nature of interviewing people about their perspectives on forests and deforestation, a longstanding source of contention between many farmers and environmentalists in the Amazon. Where more than one municipality was suitable per quartile, the diversity of rural farm-forest landscapes and land uses within other municipalities influenced the final decision (i.e. to fit characteristics we considered typical for a given frontier stage).

Deforestation frontiers were classified as ‘pre’, ‘early’, ‘intermediate’ and ‘late’. The pre-frontier stage sought to include a municipality with a low rate of recent deforestation (<0.5% primary forest deforested between 2020-2023), and with low total (i.e. cumulative) primary forest lost since 1986 (<5%). The early frontier stage was intended to capture a municipality

with a high rate of recent deforestation (>3%), and a lower proportion of total original primary forest cover lost (~10% or less). Active, intermediate frontier stage is classified here as a municipality with a high rate of deforestation (≥2.5%) and a higher proportion of total original primary forest cover lost relative to previous stages. Finally, the late frontier classification was intended to capture a municipality with a lower rate of recent deforestation, but a high proportion of original primary forest cover lost (≥30%). Our frontier stage classifications were also grounded in the rich political ecology literature (see Hecht and Cockburn, 1989; Browder and Godfrey, 1997; Little, 2001) that documents the non-linear nature deforestation frontier dynamics, which are not just characterised by a steady increase in forest loss over time, but sometimes by 'waves' of external pressures on local resources and in-migration (Schmink *et al.*, 2019). Municipalities selected for data collection were Tefé and Lábrea (pre and early frontier contexts in the central Amazon [both in Amazonas State]), and São Félix do Xingu and Paragominas (intermediate and late-stage frontier contexts in the eastern Amazon [Pará State]) (Figure 3.3).

For data collection in these municipalities, we aimed to obtain a broadly representative sample (subject to logistical constraints for rural surveys) of the whole municipal population, in order to answer the core research questions. Data sampling effort was split between urban and rural areas, proportional to the urbanization level of each municipality. Sampling efforts focused on a detailed and representative urban data collection strategy (Figure 3.4). Rural sampling locations within each municipality were selected purposively to capture the perspectives of predominant (i.e. more numerous) rural actors in particular frontier stages, rather than to represent the full diversity of rural actors. For example, in the intermediate frontier municipality São Félix do Xingu (Figure 3.3), this meant prioritizing smallholders and cattle producers, as their land-use decisions most directly influence ongoing forest conversion. We aimed to capture some variation in rural livelihoods and settlement types (e.g., long-established communities, agrarian reform settlements) while ensuring comparability across municipalities in terms of their relevance to deforestation processes. Importantly, we did not sample within Indigenous territories, as these groups were outside the scope of this study and their land governance regimes differ markedly from those driving most local deforestation. A limited number of interviews were conducted within formally recognized sustainable use reserves, primarily (n=14) in the early frontier municipality of Lábrea. This decision was taken because the inhabitants of such reserves represent an important segment of rural populations in many municipalities and excluding them entirely

would have overlooked a significant rural actor in these contexts. For example, Parry *et al.* (2025) calculate the forest citizen intensity in our study municipalities (which refers to the proportion of permanent residents living in formally recognized sustainable use reserves) to be highest in Lábrea (0.41), followed by São Félix do Xingu (0.13), Tefé (0.08), and lastly, Paragominas (0.04). At the same time, we sought to avoid over-representing reserve populations, instead prioritizing a broader diversity of rural actors that engaged with dominant modes of production in each municipality selected for this study, as well as the logistical hurdles that working solely in sustainable use reserves present. Within each municipality, sampling sites were identified through a combination of prior literature, consultations with colleagues and students at the Federal University of Pará (UFPA) and local institutions in the study municipalities, and field knowledge provided by the co-supervisor (VG) of the lead author (JOL) during his doctoral studies based at UFPA. This collaborative process helped refine site selection to ensure both scientific relevance and feasibility for fieldwork by a visiting PhD student.

The four selected municipalities differed markedly in terms of recent rates of deforestation, primary forest cover remaining, head of cattle and total pasture cover (Table 3.1). Additionally, sampled municipalities were diverse in terms of geographic area, population size, formal education, among other things, and they each have distinct political, economic and environmental histories. In other words, inevitably the four municipalities were diverse in many senses (as are any case study locations), and not just in relation to their deforestation frontier stage. For this reason, whilst they provide insights into cultural expression in different frontier contexts, the empirical findings from this study are not necessarily generalizable to other frontier situations. Tefé was considered as a highly forested pre-frontier municipality because it had a low deforestation rate (0.3% [or 63km²] of remaining forest was deforested between 2020-2023), low cumulative deforestation (251km² or 1.3% of primary forest was lost since 1986), and relatively low pasture cover (126km² or 12,600 hectares) and head of cattle (1258)(Table 3.1). This cattle stocking density (0.1 cattle/hectare of pasture) is indicative of the low productivity of extensive cattle-raising in Amazonia and this activity is only profitable over the long-term given the sale of illegally-logged hardwoods during the forest clearance process, and from potential (and somewhat speculative) increase in land prices following the conversion of forest to fenced-in pasture. In Tefé overall, the ratio of cattle to people was 0.017.

Lábrea was considered as a highly forested early-frontier municipality because it had a high deforestation rate (3.3% [or 1845km²] of remaining forest was lost between 2020-2023), intermediate cumulative deforestation (6,415 km² or 10.7% of primary forest was lost since 1986), and rapidly growing pasture cover (6,386km² or 638,600 hectares by 31/12/2023, compared with 4,609 km² or 460,935 hectares by 01/01/2020), and head of cattle (652,247 by 31/12/2023 compared with 318,676 by 01/01/2020). In Lábrea, the ratio of cattle to people was 14.3 cattle per person on average. The relatively high cattle stocking density (~1.02 cattle/hectare of pasture) suggests a shift toward more intensified pasture use, profitability continues to depend heavily on revenues from timber extraction during deforestation and on speculative increases in land values following conversion of forest to pasture, the most of which happens at or close to the southern-edge of the municipality which borders the neighbouring state of Rondônia (i.e. hundreds of kilometres from the urban centre of Lábrea; Figure 3.4)(Supplementary Figure 3.1).

São Félix do Xingu has the highest recent deforestation rate of the four municipalities included in this study (4.6% or 2,703 km²), high cumulative deforestation (20,111 km² or 27%), as well as high pasture cover (19,632 km², equivalent to 23% of the municipal land area) and an extremely large cattle herd (2,452,095 head of cattle; equivalent to 37.5 head of cattle per human inhabitant). This high cattle stocking density (1.25 cattle/ha) is indicative of a municipal economy overwhelmingly driven by beef cattle ranching, which is both the main source of local revenue and a key driver of deforestation in the region. The expansion of pasturelands to support the municipality's massive herd has historically fuelled forest clearance, while other sectors such as mining and agriculture play comparatively minor roles in the local economy. Efforts at diversifying the economy through sustainable practices like agroforestry and bioeconomy initiatives remain limited relative to the dominance of cattle ranching.

Paragominas, the late frontier municipality, has the highest proportion of original forest cover lost in this study (30% or 4,520km² cumulative deforestation by 31.12.2023), an intermediate deforestation rate (2.4% or 256km²), as well as an intermediate herd size (375,902 head of cattle) grazing 4,337km² of pasture, giving Paragominas an intermediate stocking density of 0.87 cattle/ha, and a ratio of 3.56 cattle per person in the municipality. This intermediate stocking density is suggestive of an economy that, while still featuring significant cattle ranching, the depletion of forest has led tore-orientation away from cattle and logging and towards soy bean farming and other commercial crops. Unlike São Félix do Xingu, where

beef cattle dominate both land use and revenue, Paragominas' economic profile is shaped by agribusiness, with mechanized soy cultivation driving much of the municipality's income and contributing to deforestation patterns. Cattle ranching remains important but plays a secondary role, often integrated with crop expansion and land-use change strategies typical of late frontier regions (Figure 3.3).

Table 3.1. Rates of recent deforestation (primary forest deforested between 2020-2023), percentage of original forest that had been lost by 2024 (using 1986 as baseline year for original forest cover), and total cumulative deforested primary forest (km2) between 1986 - 2023 by surveyed municipality.

Municipality (State)	**Recent deforestation (%)**	**Original forest lost (%) by 1 Jan 2024**	**Cumulative deforestation 1986 - 2023 (km2)**	**Total pasture area at 31 Dec 2023 (km2)**	**Total head of cattle (31 Dec 2023)**	**Frontier stage classification**
Tefé (Amazonas)	0.3%	1.3%	251	126	1,258	*Pre*
Lábrea (Amazonas)	3.3%	10.7%	6,415	6,386	652,247	*Early*
São Félix do Xingu (Pará)	4.6%	27%	20,111	19,632	2,452,095	*Intermediate*
Paragominas (Pará)	2.4%	30.4%	4,520	4,337	375,902	*Late*

3.2.1.1 Environmental Histories

Although deforestation and cattle-raising statistics were crucial in identifying suitable municipalities for each frontier stage, we drew heavily on political ecology insights into frontiers as contested spaces with highly contextualized rural geographies, making this equally important in selecting the study sites (Hecht and Cockburn, 1989). Each municipality has a distinct environmental history, reflecting differences in exposure to environmental stressors, road connections (or lack of) to the rest of Brazil, external market demand for beef,

the establishment of protected areas and indigenous reserves, and the timing of agricultural expansion (see Supplementary Figure 3.2).

Tefé (pre-frontier) is in the Central Amazon, which has been largely untouched by the arc of deforestation. The municipality is highly forested (98.7% of original forest remaining), with the urban area and many rural settlements lying along the Tefé River, which flows into the main Amazon River channel (called the Solimões, which is the river section between the Brazil-Peru border and Manaus). Many rural communities in Tefé and neighbouring municipalities are traditional riverine communities who reside in formally recognized Sustainable Use Reserves (which Parry et al. 2025 consider as forest citizen territories because they were created through grassroots demands for recognition and then have some form of participatory governance), with livelihoods based on small-scale fishing, harvest of non-timber forest products, shifting cultivation (especially production of toasted manioc flour, farinha) and some timber extraction. These populations of the riverine communities we sampled in Tefé and Lábrea could be described as Amazonian peasants (locally, *Ribeirinhos*, caboclos, or other terms), as described in Sections 3.1.1 and 3.1.3. Tefé has a total population (rural and urban combined) of 73,669 people and a population density of 3.11/km² (IBGE, 2022, https://cidades.ibge.gov.br/brasil/am/tefe/panorama). The urban area covers approximately 10km² (or 0.04% of the total municipal area)(IBGE, 2019), with 63,207 people (86% of all residents) inhabitants (Tefé Municipal Health Secretariat, 2024). The urban centre of Tefé is the hub city in the mid-Solimões political meso-region, providing most access to air and boat transportation, universities, government offices, and trade goods for the area's rural and urban populations (Zumak *et al.*, 2025).

Lábrea (early frontier) is located in the Southern Amazon in Amazonas state. Deforestation in Lábrea is related to illegal logging, soybean and pasture expansion from the neighbouring state of Rondônia that spills over the municipal boundaries, which originally intensified in the early 2000s (Reis and Leal, 2020). Throughout this period, illegal land-grabbing (called *grilagem*), characterised by the fraudulent occupation and titling of public lands that enables large-scale forest clearing (often for pasture), was a central driver of forest loss during this period (Pereira Santos, 2023). In response, the Federal Government supported the community-led creation of two large Extractive Reserves in the municipality in 2006 (along with several other protected areas) which allowed for stronger defence against illegal logging and land-grabs to prevent further forest losses (EJAtlas, 2025). Lábrea continues to experience cattle-related deforestation on the north-west and southern boundaries of the

municipality (Figure 3.2)(Supplementary Figure 3.1), yet also contains traditional river-dwelling populations and highly forested landscapes to the east along the Purus River and its tributaries. The urban centre of Lábrea marks the end of the Trans-Amazon highway where it meets the Purus River. Many riverine and indigenous communities reside along the Purus in protected reserves, relying on fishing and small-scale agriculture to make a living. With a total population of 45,488, Lábrea is sparsely populated with a population density of 0.67/km² (IBGE, 2022, https://cidades.ibge.gov.br/brasil/am/labrea/panorama). The urbanised area covers ~ 6 km² (IBGE, 2019) which has 30,871 residents (68% of the municipal population) (Lábrea prefecture, 2024).

São Félix do Xingu (intermediate frontier) is located in the southern Pará state and is the third largest municipality in the state with a total area of 84,213 km². Through multiple waves of successive in-migration of miners and loggers (1980s), colonists (1990s), and ranchers (2000s) (Schmink *et al*. 2019), the cattle herd size grew to be the largest in Brazil (IBGE, 2024), which was accompanied by rapid pasture expansion. São Félix contains part of the Xingu River and many indigenous territories and forest reserves, with an increasing amount of forest restoration programs being focused on the region in recent decades (Sanches, Futemma and Alves, 2021). While rural riverine (non-indigenous) residents in the municipality historically relied on extractivist forest practices and fishing, the rapid expansion of the agricultural frontier from the 1990s onwards meant that most rural communities in the area now engage with cattle rearing to varying degrees (e.g. from large-scale ranching to rearing a handful of cattle as a diversification strategy for small-scale family farming). São Félix is sparsely populated, with a total population of 65,418 people, and a population density of 0.78 inhabitants/km² (IBGE, 2022, https://cidades.ibge.gov.br/brasil/pa/sao-felix-do-xingu/panorama). The urbanised area covers approximately 19km² (IBGE, 2019), with an estimated 52,400 urban residents, constituting 80% of the municipal population (São Félix do Xingu prefecture, 2024).

Finally, Paragominas (late frontier) is located in the North-Eastern Amazon region, Pará state. Prior to the 1960s, the area now considered Paragominas was almost entirely forested, but following the completion of the Belém-Brasília Highway in 1960 and the political creation of the road-centred municipality in 1965, approximately 24% of the municipality had been converted to pasture by 1985 (Uhl and Vieira, 1989). This agricultural expansion was accompanied by particularly violent land and resource conflict centred around illegal logging and pasture creation. The municipality rapidly established a cattle-based economy, but

pasture degradation led to declining productivity within a few decades and prompted a shift toward timber extraction. By the late 1980s, Paragominas had become Brazil's leading timber-producing centre; however, within just ten years most of its forests had already undergone at least one logging cycle, leaving harvestable timber increasingly scarce (Nepstad *et al.*, 1999). Partly as a result of the dwindling forest resources in the 1990s and early 2000s, medium and large-scale landowners started experimenting with soy, plantation forestry and cattle intensification (Barros, 2003). These historical events have meant that the rural population of Paragominas is both diverse and fragmented, including many farmers who have migrated from elsewhere including southern and northeastern states of Brazil. Somewhat paradoxically, the municipality became Brazil's first 'green municipality' in 2008, which was characterised in part by reforesting initiatives and increasing large-scale agricultural efficiency rather than increased short-term production, which successfully facilitated the municipality's removal from the federal government's high deforestation red list in 2010 (Viana *et al.*, 2016). Paragominas has the largest population of all sampled municipalities in this study at 105,550 people, and a population density of 5.46/km² (IBGE, 2022, https://cidades.ibge.gov.br/brasil/pa/paragominas/panorama). The urban area covers 29km² (IBGE, 2019), with 91,398 urban residents (87% of the municipal population) and 14,152 rural residents (Paragominas prefecture, 2024).

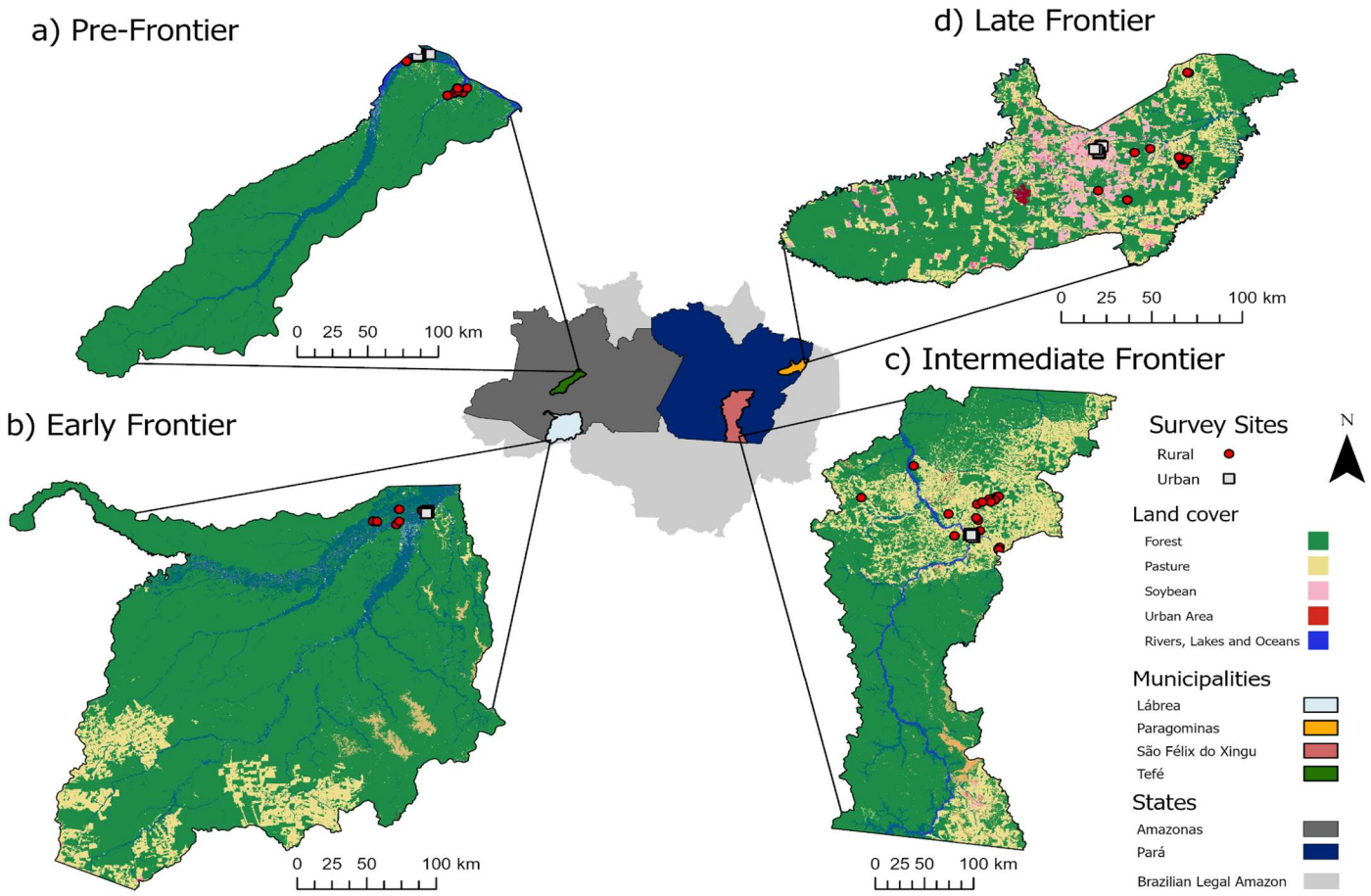


Figure 3.3. Location of the study regions in Brazilian Legal Amazon, municipalities and detailed land-cover information of each municipality where surveys were undertaken, indicating the location of the 104 study sites (urban interviews, n = 256; rural interviews, n = 151) for 407 sampled households (urban households indicated by light grey box, while rural households are indicated by red dots). *Forest cover is indicated in green, converted land (pasture) in yellow, water bodies in blue, soy plantations in pink and urban areas in bright red. Municipality is highlighted within the state in a smaller regional map in the centre of the page.*

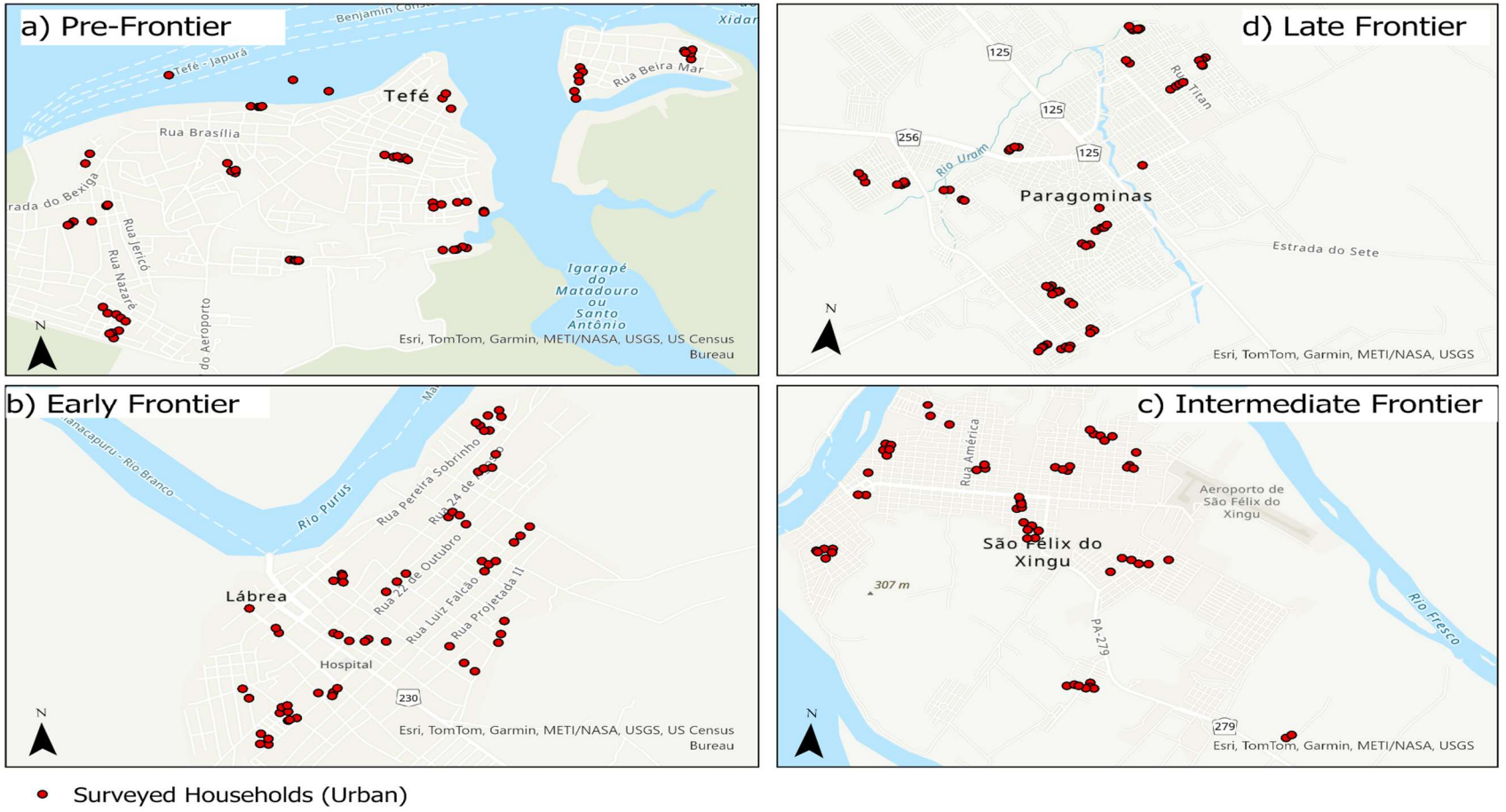


Figure 3.4. Urban area maps for each municipality separated by frontier stage: a) Pre-frontier (Tefé, top left); b) Early frontier (Lábrea, bottom left); c) Intermediate frontier (São Félix do Xingu, top right); and d) Late frontier (Paragominas, bottom right). *Interviews conducted across urban areas are shown by red dots (n = 256).*

3.2.2 Data Sampling

Each municipality differed greatly in area, population size (size and demographics), total urbanized area and proportion of rural and urban residents (Table 3.2). Urban areas varied in their geographic area (from ~6km² - 29km²) and population sizes (from 30,871 to 91,938). All municipal populations in this study were mainly urban (ranging from 68% to 87%). Field data was collected by JOL and trained local assistants between July and October 2024. Approximately one month was spent for each municipality, including travel time (sometimes days by boat from the state capital), establishing relationships with local institutions, recruiting an assistant, and collecting data in urban and rural areas.

Urban sampling was randomized and intended to capture cultural expression that was representative of the urban population. Conversely, rural sampling aimed to capture representation from a diversity of rural producers with respect to the dominant modes of production and identity categories within each municipality. As such, rural sampling was designed to capture perspectives from people living in representative landscapes from each municipality (in other words, in the highly forested pre-frontier we sampled mainly traditional forest communities whereas in the cattle-dominated late frontier we sampled mainly from largely deforested properties in which there was significant pasture and cattle). We also attempted to sample people living varying distances from the urban centre in order to avoid a potential geographic bias in terms of remoteness from people's alignment with particular forms of cultural expression.

Table 3.2. Urban area split of each municipality for population size, urbanised area, municipality size.

Municipality (State)	**Population size (IBGE, 2022)**	**Estimated urban population (% of municipal total)**	**Total urban area (km²)**	**Total municipal area (km²)**	**Population density (inhabitants per km²) (IBGE, 2022)**
Tefé (Amazonas)	73,669	63,207 (86%)	10 km²	23,693 km²	3.11
Lábrea (Amazonas)	45,488	30,871 (68%)	6 km²	68,263 km²	0.67

São Félix do Xingu (Pará)	65,418	52,400 (80%)	19 km²	84,213 km²	0.78
Paragominas (Pará)	105,550	91,938 (87%)	29 km²	19,343 km²	5.46

3.2.2.1 Urban sampling

Urban areas in each municipality consisted of multiple neighbourhoods with uneven population distribution, demographics and socio-economic conditions. Data from the official government census was only available for 2010 (since which many population transitions have occurred) and therefore for the urban sampling we relied mainly on more up-to-date information from municipal health secretariats. Urban interviews were collected in a stratified-randomised fashion across all neighbourhoods of each municipality's urban centre (in the sense that sampling effort per neighbourhood was proportional to its estimated population size, and within neighbourhoods we attempted to obtain a random sample of households). City maps were acquired from both the town hall (*prefeitura*) and municipal health authorities to understand the layout of each urban centre and to verify how neighbourhoods were partitioned by local government for administrative and healthcare purposes. According to local health secretariats (verified by lead investigator, 2024), each neighbourhood was separated into micro-areas that groups of Community Health Agents (ACS in Portuguese) were responsible for visiting on daily rounds. Neighbourhood-scale population estimates for 2024 were acquired from the health secretariat of each municipal government, and sampling effort was divided proportionally across each neighbourhood (i.e the number of interviews allocated to each neighbourhood was proportional to the population size). Micro-areas were then selected at random, with ACSs helping to map out these areas. A minimum of four micro-areas were selected per neighbourhood, with the average number of micro-areas per neighbourhood across all urban centres being eight.

Upon arrival at a micro-area, the lead investigator (JOL) located the northernmost point (according to Mapy.cz phone application and with visual direction from the local ACS), turned clockwise, and selected the second house in view. Once JOL and the accompanying ACS(s) arrived at the property, an informal introduction was facilitated by the ACS with the head of the household. JOL would then explain the research being undertaken and ask the

head of the household for permission to undertake a questionnaire with a member of the household, providing a participant information sheet with relevant contact details, a more detailed explanation of the project and JOL's affiliations. Once permission was granted, the first names of all adults (18+) residents were asked and recorded temporarily. A mobile phone app with a random number generator was then used to apply a number between one and one hundred to each name, and the head of the household was asked to pick a number within that range at random to determine which person would conduct the interview based on the closest number to the one picked. Only one interview was conducted per household. Every fifth house after the last sampled residence was then sampled until the quota for that quartile was filled, with interview refusal from this method being very low (<5%).

3.2.2.2 Rural Sampling

Rural sampling aimed to capture a representative sample of diverse rural respondent groups, with a diverse mixture of rural producers with respect to modes of production and identity within each municipality targeted for rural data collection. As such, rural sampling was conducted across a variety of terrains and communities, including those self-identifying as traditional river dwellers, or *Riberinhos* (Lábrea, Tefé); small-scale family farmers (all municipalities); colonist farmers living in *assentamentos* (agrarian reform settlements) (Paragominas); workers on cattle ranches that split time between rural-urban areas (Paragominas, São Félix do Xingu), and cattle ranchers living on (or owning and living somewhere else) medium- and large-scale cattle ranches (Paragominas, São Félix do Xingu). Each sampled social group across all municipalities have differing levels of decision-making power and influence at local scales, with traditional communities among rural samples in Lábrea and Tefé making up some of the most marginalized social groups across Amazonia with regard to the historical denial of land-tenure and formal federal recognition (Nugent, 1993; De Souza Martins, 2002; Fraser, 2018). For example, the formation of the majority of Sustainable Use Reserves (RESEX) in Lábrea are the result of allegiances between a local Evangelical church pastor and congregation of rural-dwelling small-scale family farmers demanding territorial recognition and creation of a RESEX reserve by the municipal and federal governments (Aleixo and APADRIT, 2011), not through federally or municipal government organised environmental policy recommendations.

Although most rural interviews across all municipalities were conducted with rural communities outside of a formally recognised RESEX, some rural interviews were conducted with traditional riverine communities residing within RESEX territories, primarily in Lábrea (n = 24). Riverine communities living within RESEX lands were selected for Lábrea specifically because of local contacts with a long history of cooperative working with these communities (ASPACS) in addition to Lábrea having the highest forest citizen intensity per capita (which refers to the proportion of permanent residents living in formally recognized sustainable use reserves) - Parry *et al.* (2025) calculate the forest citizen intensity in our study municipalities to be highest in Lábrea (0.41), followed by São Félix do Xingu (0.13), Tefé (0.08), Paragominas (0.04), respectively. Indigenous communities were not sought out for interviews because of the distinct cosmologies and worldviews that are held by Indigenous peoples compared with traditional peasant societies, and because obtaining official permission to conduct research with indigenous peoples in Brazil was unrealistic for a foreign researcher.

Contact with rural community leaders (and thus sampling) was done so opportunistically, making use of existing contacts in local NGOs and environmental governmental agencies (e.g. environmental agency ICMBio in Lábrea, Mamirauá Institute for Sustainable Development in Tefé). In the case of rural interviews, populations are more geographically sparse and compared to urban populations, imposing costly time and financial barriers. As such, a minimum of five rural communities (or clustered areas in situations where farms were not organized around a named, specific community centre) per municipality were targeted for rural sampling, with only Tefé falling short of this mark because of logistical and ethical constraints (four communities were sampled). Community leaders/representatives were always contacted ahead of travel to rural areas, with permission granted primarily via WhatsApp contact with JOL or trusted intermediaries. Where consent was not awarded prior to the trip or upon arrival to a community by at least one community representative, sampling effort was redirected. The same process was then applied on the rare occasion that community leaders retracted permission for rural interviews mid-trip. Due to this last point, fourteen rural interviews that were conducted were later discarded, destroyed and excluded from final analysis.

Data sampling across all municipalities also intended to capture demographic variation among both urban and rural respondents (e.g. age, gender, religion, birth municipality). Ethnographic research in various contexts of the Brazilian Amazon has demonstrated that

individuals across the biome are incredibly diverse and hold a variety of identities and cosmologies that make up the collective Amazonian population (Schmink, 2003). Within households, a number of seemingly contrasting identities and cultural values can coexist (Hoelle, 2015). As such, our data needed to take into account these varied identities when trying to understand how cultural expression changes across frontier stages.

3.2.3 Survey Instrument

Surveys were administered through face-to-face interviews using a structured questionnaire, lasting approximately 25 minutes. The survey was composed of three sections, asked sequentially: (1) *Socio-demographic characteristics and identity;* (2) *Cultural expression;* and (3) *Environmental relational values.* This study was focused on analysis of sections 1 and 2 of the survey instrument. Section 1 was concerned with identifying respondent's key social characteristics, such as religion, gender, if they self-identified with a particular rural identity category/ies (e.g. river dweller, family agriculture, colonist farmer), birth municipality and state, and some socio-economic indicators such as age, years of formal schooling, whether they were raised in an urban or rural area and assets (Global MPI, 2025). Survey items related to cultural expression (section 2) were multi-faceted, including a mixture of question types. Two of the four sections of this survey included Likert scale questions, where 1 = 'completely disagree/never listen to', and 5 = 'completely agree/always listen to' with the statement (Supplementary Table 3.1).

The cultural expression section drew on knowledge about the norms and practices associated with traditional Amazonian identities, and with cattle culture (Hoelle 2011, 2015) (Supplementary Table 3.1). Questions covered multiple aspects of cultural expression, including musical genre listening time/preferences (Likert), food preferences and consumption frequency (ranking 1-5), clothing choices (Yes/No Answer for 4 types of clothing), and finally, Likert scale questions related to traditional Amazonian cultural norms and practices, such as food, means of travel, living arrangements and cultural pastimes. The inclusion of questions related to traditional Amazonian cultural practices (which draw on riverine peasant's culture, broadly understood) was guided by the research team's extensive experience of working in rural Amazonia (collectively, 40+ years), and informed conversations between the lead investigator (JOL) and one of the project team supervisors

who is from the Brazilian Amazon (VG) during JOL's year working in the Amazonian Institute of Family Agriculture, Federal University of Pará (UFPA), Belém. The formation of questions related to cattle culture were inspired by existing literature on the spread of cattle culture (see Hoelle, 2011, 2014, 2015, 2018) and ethnographic experience of cattle frontiers among project team members (JH; VG). For example, clothing preferences (a central part of the traditional *gaúcho* or *caubói* repertoire commonly worn on ranches (Hoelle, 2011)) were chosen to represent markers of cattle culture. Because the study is concerned with how cattle culture is adopted and expressed across advancing agricultural frontiers, this measure was designed to detect patterns of cultural assimilation among both rural and urban respondents, regardless of whether they were formally engaged in cattle ranching.

An initial survey tool was constructed that aimed to capture each of the cultural markers of both traditional Amazonian and cattle cultures. A total of 21 pilot surveys were conducted in June 2024. These surveys were conducted largely on campus grounds of UFPA, Belém with visiting Family Agriculture students who were mostly from rural communities (e.g. small-scale family agricultural producers), and students from rural areas in other parts of Amazonia (e.g. Maranhão). These initial surveys aided in the refinement of survey question wording, the order of questions asked, and finally, understanding whether the survey had an initial statistical validity. Following these interviews, Cronbach's alpha test revealed the internal validity of all cultural questions to be 'poor' ($\boldsymbol{\alpha} = 0.58$). The survey instrument was thus refined, with changes being informed by the data (internal validity contributed by each survey item) and suggestions from interviewees in the pilot study.

3.2.4 Instrument validation, factor analysis, and worth scores

In order to understand how the selected cultural expression questions captured two distinct forms of culture among respondents (traditional Amazonian and cattle culture), a variety of validation analyses were conducted on the whole dataset, including Omega analysis, followed by exploratory (EFA) and confirmatory factor analyses (CFA). First, all cultural expression questions that were in Likert-scale format were grouped, and the internal validity of this grouping was checked. Although Cronbach's alpha is a generally accepted tool for assessing this, the Omega statistic (ω) generally performs better in assessing the amount of unique constructs in a single set of questions, or scale (Zinbarg *et al.*, 2005). A bi-factor omega

model was employed to understand whether all questions reliably measure one underlying construct or rather, is multidimensional, and then, how the survey items branch into related (but competing) factors, or 'sub-dimensions' (Reise, 2012). To ascertain the optimum number of factors for both sections, an 'nfactor' test was conducted to determine how many factors properly capture a meaningful proportion of the variance in the data.

To understand which survey questions were grouped together statistically (i.e. gathering data on the same underlying aspect of culture), factor analysis was conducted. First, an EFA was performed to let the data guide the factor groupings. Once an appropriate number of factors was ascertained with groupings that made sense both statistically and conceptually (based on the project teams definitions of cultural norms, behaviours and values mentioned in 'Survey Instrument' section), a CFA was performed. While EFA models help researchers to determine an initial factor structure within the selected items, CFA advances upon this by confirming factor structure and producing model fit indices to indicate how well the specified model 'fits' the data (Tavakol and Wetzel, 2020). The CFA was then used to ascertain the most appropriate composition of those factors, or 'sub-dimensions'.

All food preference data was initially treated separately. Items such as beef, chicken, fish, turtle and bushmeat were ranked relative to one another in terms of both taste and the frequency of consumption, rather than independently. This structure violates assumptions required for factor analysis of Likert-type data (Yong and Pearce, 2013). As a result, food consumption and taste preferences were modelled using ranking methods rather than included in the factor analysis explained above.

The omega results (Supplementary Figure 3.1) suggested that when taken together, the set of cultural survey questions form multiple constructs, benefitting most from three or four cultural sub-factors. The key indices that a CFA provides are Standardized Root Mean Square of Residuals (SRMR), Root Mean Square Error or Approximation (RMSEA), Robust RMSEA, Comparative Fit Index (CFI), Robust CFI, Tucker-Lewis Index (TLI) and Robust TLI. A test statistic is also provided with a Chi-Squared and corresponding p-value, however, these are often sensitive to large sample sizes and thus, should be interpreted with caution when determining the suitability of model fit. A model is considered a 'good' fit for the data when: RMSR ≤ 0.08, RMSEA ≤ 0.05, Robust RMSEA ≤ 0.06, CFI ≥ 0.95 and TLI ≥ 0.9 (Hu and Bentler, 1999). All CFA tests were conducted using a Weighted Least Squares Mean and Variance adjusted (WLSMV) estimator method, because it is more appropriate for ordinal

(e.g. Likert) data than a standard Maximum Likelihood (ML) estimation method, which relies on assumptions of distribution normality and non-kurtosis (DiStefano and Morgan, 2014).

Some survey items were judged to measure almost identical cultural concepts using a combination of factor loading interpretations from EFA results, deductive reasoning informed by in-field data collection experience of the principal investigator (JOL), and group discussions of co-authors involved in the planning and data collection stages of the project. Rather than merging these responses, the decision was taken to remove items from the model that had high covariance and measured similar concepts that, for the purposes of these analyses, overlap significantly (e.g. Samba and Pagode are unique musical genres to fans of each genre, yet are derived from the same genre and thus represent similar cultural themes (Santos *et al.*, 2021)). Responses to food consumption and preferences were first explored to understand any key characteristics and/or patterns in the raw dataset that would aid further analysis efforts (non-normality, missing data, covariation, etc). Bivariate Pearson correlations were conducted between self-reported consumption and taste preferences for five protein sources: fish, beef, chicken, bushmeat, and turtle (n = 392, Supplementary Figure 3.2).

3.2.5 Data Analysis

All data analysis was conducted in R Studio 4.5.0. Deforestation, primary forest and pasture cover data were acquired from MapBiomas (https://brasil.mapbiomas.org/estatisticas/). Municipalities included in this study were split into groups ahead of any statistical analysis conducted with factor scores, with each of the four municipalities surveyed in the study assigned to a unique frontier stage - Tefé (pre-), Lábrea (early), São Félix do Xingu (intermediate), and Paragominas (late)(Table 3.1). Once frontier stages were separated, individual factors were established first using EFA to outline data-led groups of questions (factors), followed by CFA to confirm factor group structures to answer our first research question (see Table 3.3 for final list of confirmed factors)(RQ3.1). Due to the overarching research aims of understanding the impact of the assimilation of cattle culture as a substitute for traditional Amazonian cultures with the progression of agricultural frontiers, only factor scores related to traditional Amazonian and cattle culture were used to explore research questions 3.2, 3.3 and 3.4. Food (protein) preference and consumption questions were excluded from further analysis for this reason and because the nature of the ranking data

collected did not allow for the proper integration of this data for linear modelling (which is performed for research questions 3.3 and 3.4).

We tested how expressions of Traditional Amazonian culture and cattle culture differed across deforestation frontier stages, using an initial nonparametric global Kruskal-Wallis test (RQ3.2). Dunn's post hoc tests with Bonferroni correction for multiple tests (Dunn, 1964) were also conducted to examine pairwise differences in average factor scores for both factors. Then, global Kruskal-Wallis tests were conducted to detect significant differences in cultural expressions among urban and rural interview respondents (RQ3.3). Further, to understand the key differences in cultural expression for both cultural factors between rural-urban sub-populations in different frontier stages, raw means were compared, interpreting the overlaps between standard errors and pairwise comparisons to infer significant differences. To account for potential violations of classical linear model assumptions, we employed robust linear models using M-estimation (Ronchetti and Huber, 2009). This approach provides more reliable coefficient estimates in the presence of heteroscedasticity and influential outliers—common features in observational and survey-based data collected in complex field settings such as the Amazon.

To examine whether cultural expression differed between in-migrants from outside of the Amazon and Amazon-born respondents (RQ3.4), we focused on São Félix and Paragominas because our samples from these municipalities included many such in-migrants. In Tefé and Lábrea no surveyed respondents were born outside of Amazonia (Supplementary Table 3.3). This pattern reflects the role of Tefé and Lábrea as regional hubs with predominantly local migration (i.e. people moving there from nearby smaller urban centres in search of educational opportunities and employment (Supplementary Table 3.4(Carr, 2009; Parry, Barlow and Pereira, 2014)). São Félix and Paragominas, by contrast, have extensive histories of in-migration from southern and south-eastern Brazil (Viana *et al.*, 2016; Schmink *et al.*, 2019). After creating a subset of the data for São Félix and Paragominas, we calculated sub-group means for forest and cattle cultural expression for Amazonian and non-Amazonian respondents and compared differences using estimated means (Figure 3.5). We then tested whether respondents' origin was associated with their cultural factor scores using linear regression with heteroskadasticity-robust standard errors (Simple Models). Finally, to assess robustness to socio-economic differences between Amazonian and non-Amazonian respondents, we added age, gender, religion, self-identified cultural identity as covariates to the model as independent variables. Because non-Amazonian respondents were unevenly

distributed across frontier stages, frontier stage was also included as an independent variable in this final model (Control Models). All analyses were performed in R using the stats, emmeans, sandwich and lmtest packages.

3.3 Results

Research Question 3.1) Which distinct forms of expression related to traditional Amazonian culture and cattle culture are present in Amazonian populations?

Exploratory factor analysis of the full dataset (i.e. using all 18 questions in Section 2 of the survey) demonstrated stronger factor loadings in a four factor model than a three factor model, which was initially suggested by the 'nfactor' test (Supplementary Table 3.2). The corresponding four-factor CFA included eleven of a possible eighteen survey items (Table 3.3) because model fit indices were significantly improved through the removal of these seven questions. For instance, using a hammock was a generally widespread cultural practice, and therefore loaded weakly across multiple factors rather than strongly with the traditional Amazonian factor. This was also the case for Gospel music, which seemingly did not fit conceptually nor statistically with the other aspects of cultural expression, which would suggest this cultural practice is distinct from the four cultural factors.

Based on our interpretation of the three questions which constituted each of the four factors, these distinct cultural expression factors were named and characterised as: Traditional Amazonian culture (expressing a keen enjoyment of traditional regional foods that have been key to livelihoods of traditional peoples [e.g. Açaí] and an expression of loss of traditional foods and cultural norms were one to move away from the Amazon); Cattle culture (the frequent use of cowboy styled clothing, expression of desire to attend rodeos, and regular listening to Sertanejo music); Traditional musical preferences (regular listening to Samba, MPB, and Carimbó); and Popular musical preferences (regular listening of Brega, Forró and Sertanejo). Musical genres that were included in these four factors were not geographically specific musical sub-categories because the traditional genres that were identified included one specific to the eastern Amazon (Carimbó) and two others from across Brazil. Likewise, the popular musical preferences factor includes one genre most characteristic of eastern Amazonia (Brega), that are popular across Brazil. Sertanejo music listening had a strong factor weighting in both the Cattle culture and Popular music factors.

The four-factor CFA model demonstrated excellent model fit indices results (RMSEA = 0.059, CFI = 0.977, TLI = 0.965, SRMR = 0.059). However, the robust fit values indicate some model misfit (Robust CFI = 0.916, Robust TLI = 0.885, Robust RMSEA = 0.092, SRMR = 0.063), especially in relation to the robust RMSEA and robust TLI. These values were slightly above/below generally acceptable thresholds, but the model remains interpretable and well-identified conceptually, presenting a reasonable harmony between statistical robustness and theoretical soundness.

There was a significant negative correlation between the traditional Amazonian and cattle culture factors ($r = -0.36, p < 0.001$), suggesting some opposing constructs being measured between traditional Amazonian culture and cattle culture factors in the factor analysis. Factor covariance was especially strong between the Traditional musical preferences and Popular musical preferences factors ($r = 0.82, p < 0.001$), suggesting distinguishable yet related sub-constructs related to musical preferences within the overall factor structure.

Summarising, exploratory and confirmatory factor analyses identified four distinct but related dimensions of cultural expression in our dataset: Traditional Amazonian culture, Cattle culture, Traditional musical preferences, and Popular musical preferences. These factors capture meaningful variation in how individuals engage with regional foods, clothing, leisure activities, and musical tastes, with some overlap between musical preference domains. Traditional Amazonian and Cattle culture factors appear to reflect opposing orientations, whereas traditional and popular musical preferences are closely related, highlighting both the diversity and structure of cultural expressions across the sample. Overall, the factor structure is conceptually coherent and interpretable. The significant negative correlation between traditional Amazonian and cattle culture factor scores supports the use of these factors in subsequent analyses as theoretical and conceptual opposites.

From here on, this paper focuses on the Traditional Amazonian and Cattle culture factors. While the two additional musical factors help illustrate broader variation in Amazonian musical preferences, they include genres not directly conceptually tied to either cultural identity. For example, only Carimbó could reasonably be linked to Traditional Amazonian culture, while Brega is more representative of metropolitan Amazonian culture (e.g. Belém) than of interior frontier regions. By contrast, Sertanejo — which loaded strongly on both the popular music and cattle culture factors — is widely recognized as central to cattle culture (Dent, 2009; Hoelle, 2014, 2015). For this reason, the analyses that follow concentrate on the

two factors most conceptually aligned with the paper's aims: to quantify cultural expression related to traditional Amazonian forest cultures and cattle culture, and to evaluate their change across deforestation frontiers.

Table 3.3. Confirmatory Factor Analysis (CFA) model comparisons with included survey items, factor loadings and model fit indices. CFA model fit indices benefitted from a higher number of factors which included two separate forms of music factors (both current and traditionally popular), one factor related to traditional Amazonian foods and regional fruits important for local identities, and finally, a factor related to the preference and regular use of cowboy clothing, a desire to attend rodeos and frequent listening of Sertanejo music (cattle culture).

Three and four-factor CFA models with Items retained in each model, corresponding factor & factor loadings, and model fit indices			
	Factor 1	Factor 2	Factor 3
Music.Samba	0.759		
Music.Rock	0.668		
Music.Brega	0.820		
Music.MPB	0.697		
Music.Carimbo	0.714		
Culture.FaltaComida		0.594	
Culture.ComidaTipica		0.815	
Culture.AcaiPuro		0.526	
Culture.FrutasRegion		0.625	
Music.Sertanejo			0.756
Music.Forro			0.921
Culture.Rodeo			0.258
Model Fit Indices			
RMSEA - 0.086 (**poor**); Robust RMSEA - 0.139 (**poor**);			
SRMR = 0.087 **(poor)**;			
CFI - 0.944 (**close to acceptable**); Robust CFI - 0.802 (**poor**);			
TLI = 0.928 (**close to acceptable**); Robust TLI - 0.743 (**poor**)			

Four Factor Model (FINAL)	Traditional Music	Popular Music	Traditional Amazonian	Cattle Culture
How often do you listen to Samba?	0.764			
How often do you listen to Carimbó?	0.709			
How often do you listen to MPB?	0.740			
How often do you listen to Sertanejo?		0.604		
How often do you listen to Forró?		0.911		
How often do you listen to Brega?		0.810		

I miss typical Amazonian food if I don't eat it	0.448
When I was a child, I ate lots of typical Amazonian food	0.747
I think the regional fruits of Amazonia… (such as Tucumã or Pupunha) are delicious	0.652
I would really like to go to a rodeo	0.525
Do you generally wear a cowboy hat, boots, belt and clothing?	0.566
How often do you listen to Sertanejo?	0.481

Model Fit Indices
RMSEA - 0.062 (**acceptable**); Robust RMSEA - 0.095 (**poor**)
SRMR = 0.059 **(acceptable**);
CFI - 0.977 (**excellent**); Robust CFI - 0.925 (**acceptable**)
TLI - 0.965 (**excellent**); Robust TLI - 0.885 (**close to acceptable**)

Research Question 3.2) How does expression of traditional forest culture and cattle culture change across deforestation frontiers?

Expression of both the traditional Amazonian culture and cattle cultural factors varied markedly across frontier stages (*Global Kruskal-Wallis* $\chi^2 > 76.5$; $p < 0.001$). Cultural alignment with traditional Amazonian cultural norms was significantly higher among the pre-frontier population of Tefé (*Mean factor score = 0.13 ± 0.03*)(Table 3.4) and early frontier population of Lábrea (*Mean factor score = 0.23 ± 0.03)* than among the population of intermediate São Félix do Xingu (*Mean factor score = -0.28 ± 0.04*) and late frontier population of Paragominas (*Mean factor score = -0.17 ± 0.03*), which was confirmed by pairwise nonparametric Dunn tests (Figure 3.5)(adj. $p < 0.001$). This alignment with traditional Amazonian cultural norms was not significantly different between pre and early frontier municipality populations ($p = 0.44$), nor between intermediate and late-stage frontier municipal populations ($p > 0.99$).

Cattle culture expression was significantly lower in pre-frontier Tefé (mean = 0.18 ± 0.03 SE, $p < 0.001$) and early frontier Lábrea (mean = 0.08 ± 0.03 SE, $p < 0.001$), compared to intermediate frontier São Félix (mean = 0.33 ± 0.05 SE, $p < 0.001$). The population of late-frontier Paragominas (mean = 0.00 ± 0.03 SE*)* expressed significantly stronger affiliation

with cattle culture than in Tefé ($p < 0.01$), but significantly lower than in São Félix ($p < 0.001$).

In summary, our results demonstrate that, at the municipal population scale, forms of cultural expression differed markedly across the four deforestation frontier contexts. Pre-frontier populations in Tefé and early frontier populations in Lábrea showed strong affiliation with traditional Amazonian culture. There is tentative evidence that traditional Amazonian culture has been displaced by cattle culture in intermediate-stage São Félix do Xingu. Importantly, while traditional Amazonian culture was lower among late-stage frontier populations in Paragominas compared to pre- and early-frontier populations, expression of cattle culture in late-stage Paragominas was not significantly higher than in Lábrea. This may indicate that neither type of cultural expression dominates strongly in this late-frontier context, despite high cumulative deforestation.

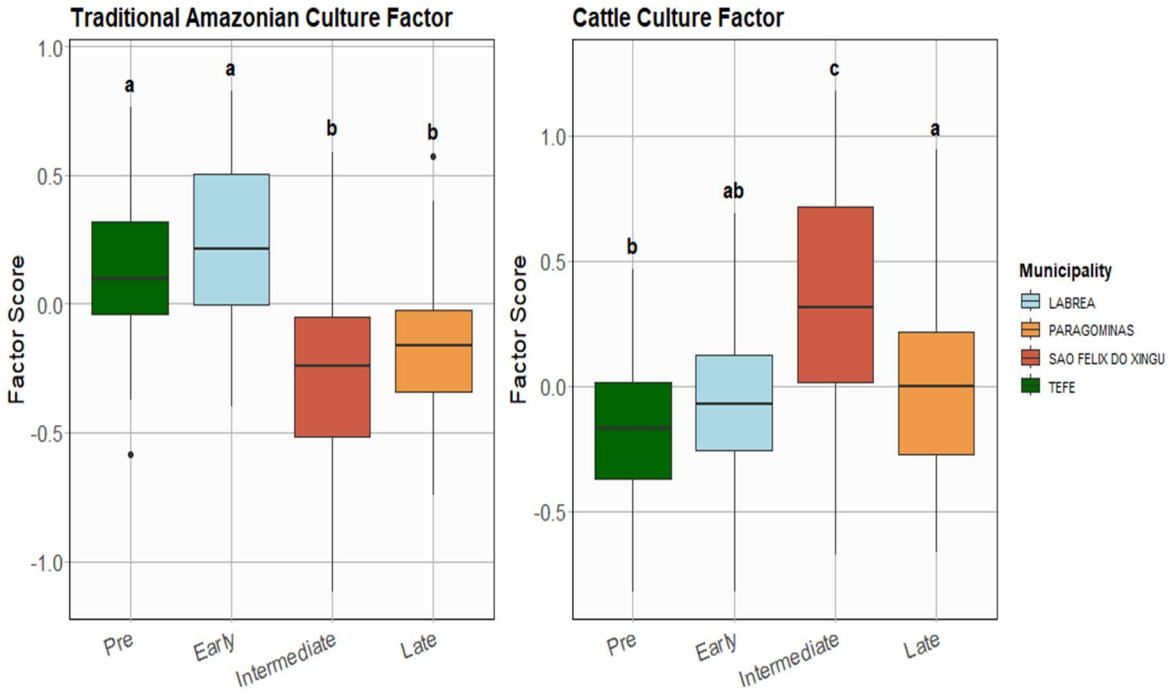


Figure 3.5. Boxplots of culture factor scores separated by frontier stage, colour coded by municipality, shown from pre-frontier (Tefé, AM) on the left to late frontier (Paragominas, PA). *Letters above each municipality box represent whether there is a significant difference in the distribution of factor scores by municipality (or frontier stage), based on Dunn's Tests for multiple pairwise comparisons (e.g. where two boxes with 'a' above indicate no significant difference between those two municipalities, but boxes with 'a' and 'b' respectively indicate significant differences between these municipalities.*

Table 3.4. Descriptive statistics (mean ± SE) of traditional Amazonian culture and cattle culture factor scores across frontier stages (with named municipalities for each frontier stage in brackets).

Frontier Stage	**Traditional Amazonian Culture Factor Score**	**Cattle Culture Factor Score**
Pre (Tefé)	0.13 ± 0.03	-0.18 ± 0.03
Early (Lábrea)	0.23 ± 0.03	-0.08 ± 0.03
Intermediate (São Félix do Xingu)	-0.28 ± 0.04	0.33 ± 0.05
Late (Paragominas)	-0.17 ± 0.03	0.00 ± 0.03

Research Question 3.3) Does the level of expression of traditional Amazonian culture and cattle culture differ between rural and urban populations?

Overall, there were no significant rural/urban differences in expression of traditional Amazonian culture or cattle culture (n = 411) (Global Kruskal-Wallis $\chi^2 > 0.79$; $p > 0.1$). The only evidence we found of stage-specific rural/urban differences in traditional Amazonian culture was higher expression in urban Lábrea (mean factor score = 0.30 ± 0.04 SE)(Table 3.5) compared to rural respondents there (mean factor score = 0.13 ± 0.03 SE) ($KW\ \chi^2 = 8.83$; $p < 0.01$). Interestingly, Lábrea's urban population held stronger affiliation with traditional Amazonian cultural norms than all other sub-populations (Figure 3.6).

Expression of cattle culture was highest among rural people in intermediate stage São Félix (m*ean factor score* = 0.42 ± 0.08 SE)(Figure 3.6), albeit cattle culture was still strongly expressed by urban residents in that municipality (m*ean factor score* = 0.27 ± 0.05 SE)(Figure 3.4). Relative to São Félix, cattle culture affiliation tailed off somewhat among rural (mean factor score = 0.42 ± 0.08 SE) and urban (mean factor score = 0.42 ± 0.08 SE) respondents in the late stage Paragominas, although still higher than pre- or early frontier levels (Figure 3.4). In the pre-frontier Tefé, cattle culture expression was very low among both urban (mean factor score = -0.19 ± 0.03 SE) and rural respondents (mean factor score = -0.16 ± 0.05 SE)($p = 0.601$).

Notably, rural people in the intermediate stage São Félix demonstrated the lowest affiliation with traditional Amazonian culture, relative to other sub-populations (mean factor score = -0.30 ± 0.06 SE). Rural respondents in Paragominas also demonstrated lower affiliation with traditional Amazonian culture (mean factor score = -0.23 ± 0.04 SE) than rural sub-populations in pre- and early frontier municipalities (Table 3.5).

Across the other frontier stages, rural and urban sub-populations largely overlapped in their expression of traditional Amazonian culture and cattle culture, with ±1 SE intervals of factor scores indicating no meaningful differences between settlement types (e.g. Tefé: *Traditional Amazonian culture:* 0.09–0.17 vs 0.10–0.16; Cattle Culture -0.21–-0.11 vs -0.22–-0.16; and Paragominas: *Cattle Culture:* -0.03–0.09 vs -0.04–0.02) (Table 3.5, Figure 3.6). This pattern suggests that, outside of the stage-specific differences highlighted in Lábrea and São Félix, rural and urban populations maintain broadly similar cultural orientations within each frontier stage.

In summary, urban and rural sub-populations in the same municipality held largely similar affiliations with traditional Amazonian and cattle culture, with some exceptions. Urban respondents in Lábrea and Paragominas expressed higher traditional Amazonian cultural markers than their rural counterparts, whereas rural/urban differences were non-significant in Tefé and São Félix. Traditional Amazonian culture was least pronounced among rural people in the intermediate frontier stage; for example, 50% of rural respondents in São Félix said they would not miss traditional Amazonian food, compared to 90% and 98% in Tefé and Lábrea respectively. Rural sub-populations in São Félix and Paragominas showed stronger cattle culture expression than urban respondents, increasing from pre-frontier to intermediate stages. For instance, 0% of rural respondents in pre-frontier Tefé regularly wore *cauboi* clothing, whereas 45% did in São Félix. In late frontier Paragominas, cattle culture remained high, similar to pre-frontier Lábrea, as illustrated by regular Sertanejo listening (45% vs 48%) and interest in attending rodeos (45% vs 47%).

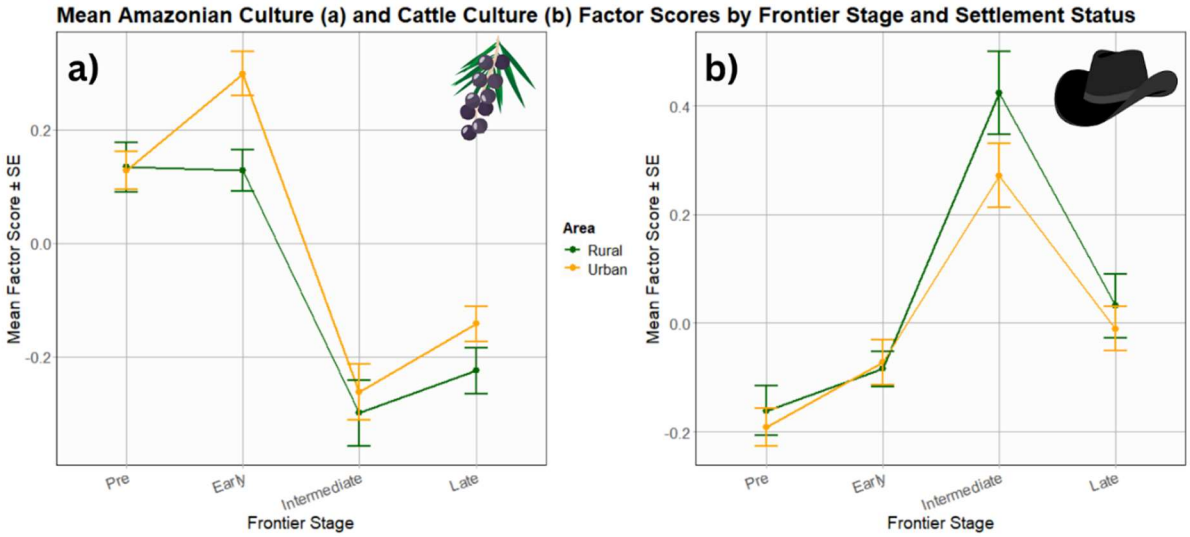


Figure 3.6. Mean factor scores and standard error bars for both traditional Amazonian culture factor scores (subplot a) and cattle culture factor scores (subplot b).

Table 3.5. Descriptive statistics (mean ± SE) of traditional Amazonian culture and cattle culture factor scores across rural and urban areas between frontier stages (with named municipalities for each frontier stage in brackets), and the number of interviews per rural/urban area in each frontier stage.

Rural/Urban, Frontier Stage	**Traditional Amazonian Culture Factor Score**	**Cattle Culture Factor Score**	**Number of interviews**
Rural, Pre (Tefé)	0.13 ± 0.04	-0.16 ± 0.05	43
Urban, Pre (Tefé)	0.13 ± 0.03	-0.19 ± 0.03	69
Rural, Early (Lábrea)	0.13 ± 0.03	-0.08 ± 0.03	41
Urban, Early (Lábrea)	0.30 ± 0.04	-0.07 ± 0.04	67
Rural, Intermediate (São Félix do Xingu)	-0.30 ± 0.06	0.42 ± 0.08	34
Urban, Intermediate (São Félix do Xingu)	-0.26 ± 0.04	0.27 ± 0.05	57

Rural, Late (Paragominas)	-0.23 ± 0.04	0.03 ± 0.06	33
Urban, Late (Paragominas)	-0.14 ± 0.03	-0.01 ± 0.03	60

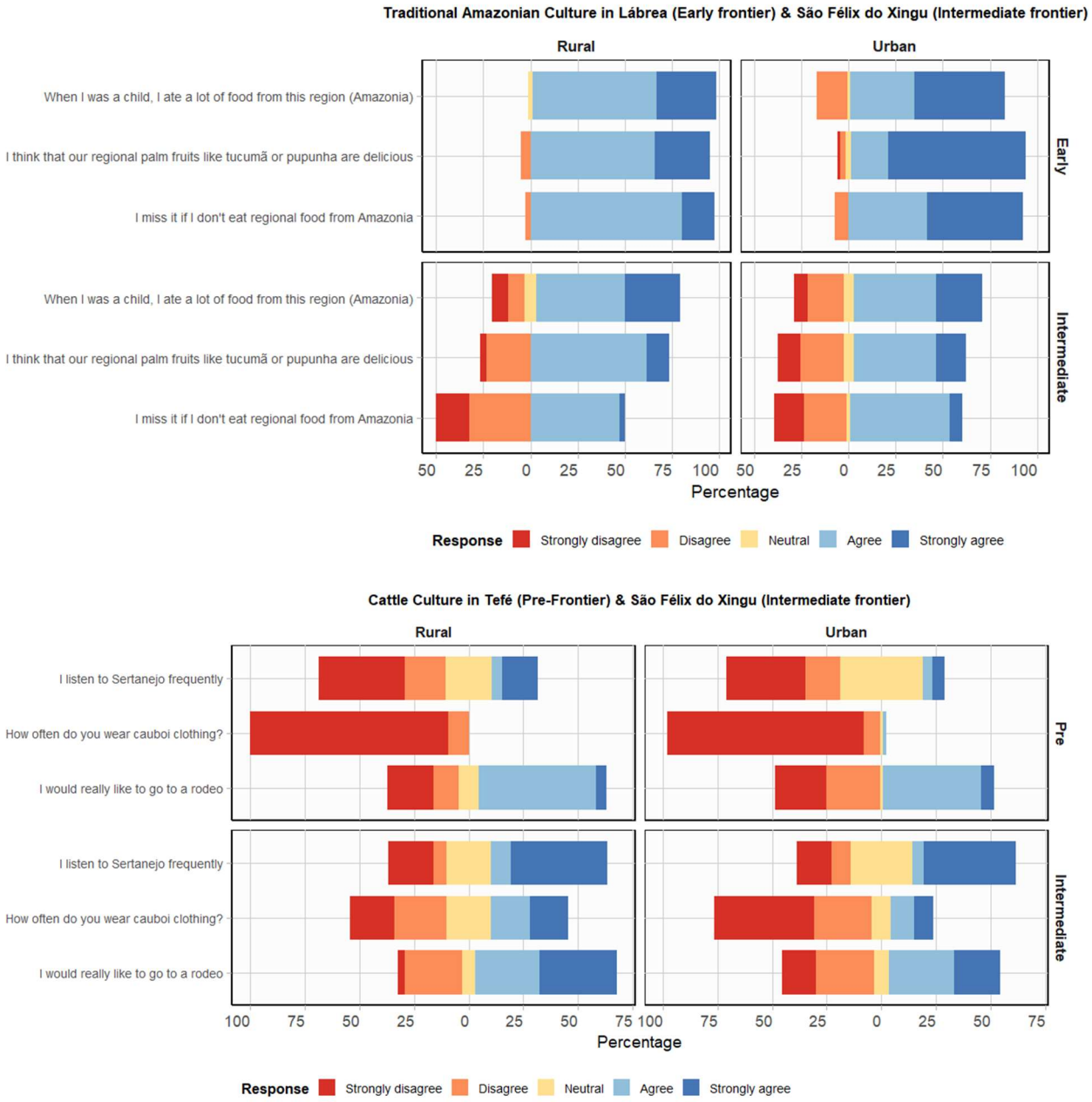


Figure 3.7. Traditional Amazonian factor (Top) and cattle culture factor questions and response frequencies (Bottom) from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages. *Amazonian cultural expression responses are shown for the early and*

intermediate frontier stage municipalities, while cattle culture responses are shown between the pre- and intermediate frontier stage municipalities to demonstrate significant differences between cultural expression in different frontier contexts.

Research Question 3.4) At frontiers, do migrants from outside Amazonia have different cultural markers than people born in the Amazon?

In the pooled sample of respondents in São Félix and Paragominas (including both urban and rural samples), non-Amazonian respondents had significantly lower markers of traditional Amazonian culture (Estimated mean = *-0.26, SE = 0.060*, $p < 0.001$)(Table 3.7) compared to Amazonian respondents (Estimated mean = *-0.17, SE = 0.023*)(Figure 3.8). Conversely, non-Amazonian respondents had significantly higher markers of cattle culture in our sample (Estimated mean = *0.21, SE = 0.073*, $p = 0.005$) relative to Amazonian respondents (Estimated mean = *0.12, SE = 0.034*).

Table 3.7. Estimated mean (± SE) of traditional Amazonian culture and cattle culture factor scores between Amazonian and non-Amazonian respondents. Tukey adjusted lower and upper 95% confidence intervals are provided after each estimated mean in the following column, and the number of interviews per group is provided in the last column.

Survey respondent origin	**Traditional Amazonian Culture Estimated Mean (± SE)**	**Adjusted Lower Conf. Interval, Higher Conf. Interval (95%)**	**Cattle Culture Estimated Mean (± SE)**	**Adjusted Lower Conf. Interval, Higher Conf. Interval (95%)**	**Total respondents**
Amazonian	-0.17 (± 0.02)	(*-0.22*, *-0.12*)	0.12 (± 0.03)	(*-0.52*, *-0.34)*	149
Non-Amazonian	-0.43 (± 0.05)	(*-0.52*, *-0.34)*	0.33 (± 0.07)	(*-0.52*, *-0.34)*	37

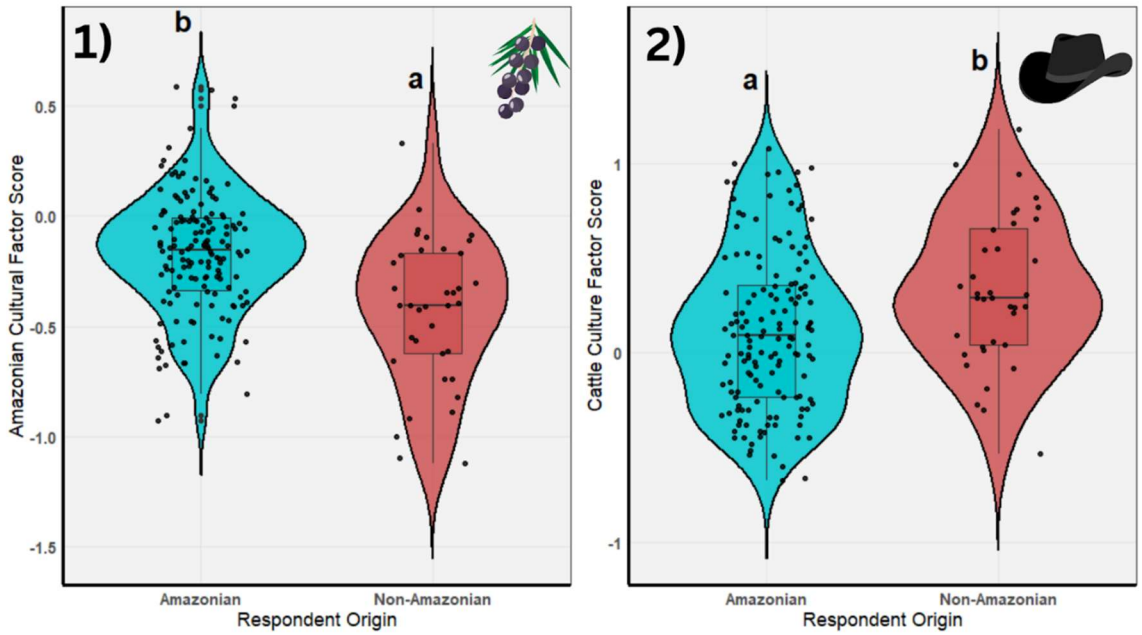


Figure 3.8. Violin plots with grouped boxplots illustrate the variation in cultural expression scores between Amazonians and non-Amazonians in São Félix and Paragominas (intermediate and late-stage frontiers). *Pairwise significance letters have been added above each group to indicate statistically significant differences between Amazonians and non-Amazonians ($p < 0.05$). The plot highlights differences in central tendency and distribution shape within each group. The left side subplot shows Amazonian cultural factor scores (1) and the right hand side subplot shows cattle culture factor scores (2). Pairwise difference letters provided are specific to each subplot, meaning that groups (a) are not compared to one another, but only to group (b) in the same sub-plot.*

Simple models: When modelling the effect of migration history using robust standard errors, non-Amazonian respondents demonstrated significant lower markers of traditional Amazonian culture than Amazonian respondents ($\beta = -0.26$, $SE = 0.060$, $p < 0.001$)(Table 3.8). Consistent with the estimated means, non-Amazonian respondents held significantly higher markers of cattle culture than Amazonian respondents ($\beta = 0.21$, $SE = 0.073$, $t = 2.85$, $p = 0.005$)(Figure 3.8). Taken together with the estimated means, these results indicate that being born outside of Amazonia is a key predictor of cultural orientation with traditional Amazonian and cattle cultures, even after accounting for unequal variance between groups.

Table 3.8. Robust Standard error linear regression models of traditional Amazonian and cattle culture factor scores. Model terms are indicated in the second column, and estimates, robust std. Errors, t-values, and p-values (with *** indications for significant effects) are shown in subsequent columns (Simple Models).

Dependent Variable	Model	Estimate	Robust SE	t-value	p-value
Traditional Amazonian culture factor score	Amazonian (Intercept)	-0.170	0.023	-7.46	$p < 0.001$***
	Non-Amazonian	-0.260	0.060	-4.34	$p < 0.001$***
Cattle culture factor score	Amazonian (Intercept)	0.117	0.034	3.42	$p < 0.001$***
	Non-Amazonian	0.209	0.073	2.85	$p = 0.005$**

Control models: Non-Amazonians showed significantly lower markers of traditional Amazonian culture than Amazonian respondents ($\beta = -0.228$, $p < 0.001$), even when controlling for potential socio-demographic differences between these groups using robust estimates of standard errors (Table 3.9). Perhaps not surprisingly, self-identification as belonging to a traditional community (e.g. river dweller, family farming, descendent of Indigenous peoples) was associated with higher traditional Amazonian cultural markers ($\beta = 0.119$, $p = 0.024$). In contrast, other socio-demographic characteristics — including age, gender, identification with being a rural producer (e.g. Rancher, Ranch Worker, Small-scale soybean producer) or Colonist, religious affiliation, and frontier stage — did not have significant effects on Amazonian factor scores (all $p > 0.05$). These results highlight that migration history and self-identification as a member of a traditional community are the primary predictors of Amazonian cultural alignment in this sample, whereas other socio-demographic or geographic factors appear to be less influential.

Conversely, non-Amazonians demonstrated stronger markers of cattle culture than Amazonian respondents, though this difference became only marginally significant in the control model ($\beta = 0.127$, $p = 0.07$)(Table 3.10). Interestingly, gender and religion had

significant effects on cattle culture among respondents. Males tended to show stronger markers of cattle culture than female respondents ($\beta = -0.181, p = 0.001$). Evangelical respondents scored lower than those who identified as Catholic or Protestant ($\beta = -0.358, p < 0.001$). Additionally, respondents in Paragominas exhibit lower markers of cattle culture compared to respondents in São Félix ($\beta = -0.240, p < 0.001$), confirming previous results reported in research questions two and three of this study. Other socio-demographic factors — including age and being from a traditional community, rural producer or Colonist community — did not significantly predict affiliation with cattle culture (all $p > 0.05$). Overall, these results suggest that gender, religion, and frontier stage are the main socio-demographic and geographic correlates of cattle culture alignment in our sample.

Table 3.9. Robust standard error linear model of Amazonian factor scores including socio-economic covariates (Control Model #1).

Variable	Estimate (β)	Robust Std. Error	t-value	p-value
Amazonian (Intercept)	-0.162	0.111	-2.77	$p < 0.01$**
Non-Amazonian	-0.228	0.064	-3.53	$p < 0.001$***
Age	-0.001	0.001	-0.64	$p = 0.524$
Gender (Female)	0.057	0.045	1.25	$p = 0.211$
Identity Group (Traditional Community)	0.119	0.052	2.28	$p = 0.0236$*
Identity Group (Rural Producer)	0.013	0.0787	0.17	$p = 0.864$
Identity Group (Colonist Community)	-0.003	0.077	-0.04	$p = 0.969$

Religious Group (Traditional/Non-Evangelical)	0.091	0.074	1.24	*p = 0.217*
Religious Group (Evangelical)	0.085	0.076	1.11	*p = 0.267*
Frontier Stage (Late)	0.045	0.046	0.97	*p = 0.333*

In summary, migration history strongly shapes cultural alignment in our sample: Non-Amazonian respondents show lower markers of traditional Amazonian culture, and to a lesser extent, higher markers of cattle culture, compared to Amazonian respondents. Our results suggest that traditional community identity reinforces Amazonian cultural markers, while gender, religion, and frontier stage are the key socio-demographic correlates of cattle culture. Overall, traditional Amazonian cultural expression is primarily linked to migration history and traditional identity, whereas cattle culture is seemingly shaped more by social and geographic context.

Table 3.10. Robust standard error linear model of Cattle culture factor scores including socio-economic covariates (Control Model #2).

Variable	**Estimate (β)**	**Robust Std. Error**	**t-value**	**p-value**
Amazonian (Intercept)	0.724	0.115	6.26	*p < 0.001***
Non-Amazonian	0.127	0.071	1.79	*p = 0.07*
Age	-0.002	0.001	-1.33	*p = 0.186*
Gender (Female)	-0.181	0.056	-3.26	*p = 0.0013***
Identity Group (Traditional Community)	-0.107	0.069	-1.55	*p = 0.124*

Identity Group (Rural Producer)	-0.005	0.088	-0.06	*p = 0.953*
Identity Group (Colonist Community)	-0.073	0.079	-0.93	*p = 0.354*
Religious Group (Traditional/Non-Evangelical)	-0.122	0.097	-1.26	*p = 0.207*
Religious Group (Evangelical)	-0.357	0.098	-3.64	*p < 0.001*
Frontier Stage (Late)	-0.240	0.057	-4.19	*p < 0.001*

3.4 Discussion

Land use land cover change has been widely examined using economistic and environmental approaches, yet the long-asserted relationship between land-use change and human culture (Lambin, Geist and Lepers, 2003) remains understudied and opaque (Caldas *et al.*, 2015; le Polain de Waroux *et al.*, 2021). Recent work has aimed to understand culture's role in LULLC, including for social-ecological systems which have global significance for sustainability and climate change, such as the Brazilian Amazon (Hodel, le Polain de Waroux and Garrett, 2024). Anthropological work has demonstrated how positive cultural associations with cattle may be contributing to the conversion of forested landscapes in the Amazon to pasture (Hoelle, Gould and Tauro, 2022). Yet, to date, there has been little exploration of how these identities may displace cultural identities and the sustainable land-use practices associated with traditional Amazonian peasant communities. Further, empirical evidence is needed to understand how these cultural constructions change with increasing deforestation and agricultural intensification across Amazonia. This study is the first (to the authors knowledge) to use a quantitative approach to examine cultural expression and environmental change across tropical deforestation frontiers, building on previous work that examined the relationship between cultural values and environmental change on a local scale in one frontier context (Hoelle, 2018). Comparing four Amazonian municipalities in different stages of deforestation frontier advance, this study adopts a novel approach to examine tensions between traditional place-based forest cultural identities and cattle culture, a

relatively new cultural identity to the Brazilian Amazon which has arrived with in-migration and cattle ranching (see Hoelle, 2011, 2014, 2015, 2018). Our findings demonstrate the role of deforestation in the expression of these cultural markers, and how cattle culture expression (including assimilation and affiliation) intensifies in rural, intermediate frontier areas, especially among people born in this frontier context, even when controlling for socio-economic differences between migrants and local people.

We found that cultural expression was influenced by ongoing and historical deforestation, but this varied somewhat between rural and urban populations in the same municipality. Cultural expressions associated with cattle culture were very strong among rural respondents in the intermediate frontier stage of São Félix, while the strongest affiliation with traditional Amazonian culture was among urban respondents in the early frontier Lábrea. Non-Amazonians demonstrated higher average affiliation with cattle culture, and lower agreement with traditional Amazonian culture than Amazonian-born respondents. Importantly, our results showed that, while association with traditional Amazonian culture was high among both rural and urban sub-populations of pre- and early frontier municipalities, these cultural constructions were seemingly eroded in the intermediate frontier (São Félix do Xingu), replaced by positive cultural associations with cattle, the driver of most Amazonian deforestation (Pendrill *et al.*, 2022). Interestingly, this effect was most significant among non-Amazonians now living in São Félix do Xingu, even after controlling for socio-economic differences between migrants and locals, suggesting that the decreasing cultural association with traditional Amazonian culture and subsequent replacement with cattle culture is perhaps both a product of in-migration and the largest cattle herd size in all of Brazil (IBGE, 2019). Together, these findings provide empirical evidence that cultural expression of rural and urban Amazonians may transform in response to forest loss and in-migration from outside of Amazonia, and importantly, when this forest loss is replaced by pasture for cattle ranching, something that has been previously been hypothesized in ethnographic studies of cattle culture in the Western Brazilian Amazon (Hoelle, 2011, 2014, 2015).

Our findings are congruent with recent cases made for culture's inclusion in the study of land system science, and thus LULLC (Hodel, le Polain de Waroux and Garrett, 2024). Primarily, our results underscore how culture can change in response to different land uses (Wu, 2010), or in this case, landscape degradation. Through demonstrating changing cultural expression

empirically, we contribute to the literature that examines cultural identity displacement as a result of agricultural frontier advance (Thaler, Viana and Toni, 2019; Costa *et al.*, 2024; Hecht *et al.*, 2024) in new and novel ways. Most importantly, we highlight that the spread of cattle culture appears to be intimately linked with frontier advance (Hoelle, 2017), an advance which is synonymous with the decline of traditional Amazonian *forest* cultures (Salisbury and Schmink, 2007). The latter is characterised by forest-centric livelihoods, landscapes and identities and - when interlinked with grassroots struggles for recognition and territory – has a political dimension through manifestation of forest citizenship (Parry *et al.*, 2025). We assert that culture is indeed a critical aspect of LULCC, and thus, warrants careful consideration in forest conservation discourse and policymaking (Adger *et al.*, 2013), something that could be aided by further empirical studies similar to the one we have conducted.

3.4.1 Deforestation and linkages with Amazonian culture and cattle culture

We demonstrate that cultural expression in Amazonia is strongly associated with the landscapes that people live and work in. The effect of this association, based on our results, is that when forested landscapes undergo significant ecological simplification - which includes through the violent dispossession of lands of traditional peoples, continued ecological marginalisation of peasant communities, and their subsequent struggles for recognition across the Brazilian Amazon (Nugent, 1993; Schmink, 2003; Fraser, 2018; Levers *et al.*, 2021) - there is a residual loss of cultural identification with traditional Amazonian peasant identities and cultures, many of which, critically, have sustainably utilized forests for long time periods (Hecht and Cockburn, 1989). Importantly, our results suggest that the opposite effect is true for cattle culture, a cultural identity that is characterised by positive cultural constructions associated with cattle and pasture, and ideals of *progress* and more pervasive *control* of landscapes (Hoelle, 2015, 2018). We found that these patterns of change in both forms of cultural expression were relatively uniform across rural and urban sub-populations, and among Amazonians and non-Amazonians (albeit to greatly different extents), suggesting that landscape composition has a significant influence on cultural expression. However, it remains unclear from our findings, grounded in space-for-time substitution, how cultural transformations away from traditional peasant cultural identities and towards cattle culture may influence attitudes towards the environment, or other adjacent themes that may predict environmental beliefs and behaviours, such as relational environmental values.

We found significant variation in the two main modes of cultural expression (i.e. putting aside the two musical cultural factors we identified) examined in this study across frontier stages, with few local rural/urban cultural differences across frontier stages. Importantly, cultural change did not necessarily follow an expected linear pattern with deforestation and is likely to be shaped by other factors, too. For instance, the particularly high association with traditional Amazonian culture in early frontier Lábrea compared with pre-frontier Tefé may be explained by Lábrea's relative isolation on the River Purus (five days boat journey from the state capital, Manaus) and its smaller urban population, which contrasts with Tefé's more heterogeneous population composed of migrants from elsewhere in Brazil and Amazonia, partly due to large military bases and other government institutions (Parry et al. 2018). Furthermore, the urban centre of Lábrea is on the Purus riverside and far from the main recent deforestation activity (see Supplementary Figure 3.1b and compare with our early-frontier sample in Figure 3.4), albeit there is deforestation and cattle-ranching along the Trans-Amazon highway, whose terminus is the urban centre. Interestingly, the study-wide high in traditional Amazonian cultural expression among urban-dwelling people in Lábrea may indeed be due to the strong history of resistance that traditional peasant communities, often led by local grassroots organisations (for example, Aleixo and APADRIT, 2011) have consistently put up against agricultural expansion and destructive encroachment on the forest in this region.

This taken with our other results implies that while cultural expression appears to be influenced by agricultural frontier advance, a strong historical precedent of culturally grounded socio-political resistance may reinforce cultural identities associated with traditional Amazonian forest cultures, despite the general impact of cattle ranching and migration on cultural homogenisation elsewhere in the region (Hoelle, 2018). In this sense, this suggests that cultural trajectories at farm-forest frontiers are not solely determined by ecological or economic transformation but are also shaped by locally contingent social histories of resistance, mobility, and identity, which can produce divergences from linear models of cultural change (Little, 2001; Hecht, 2015; Thaler, 2024).

The strong association with cattle culture in São Félix is unsurprising given this municipality has 2.5 million head of cattle, the highest of any in Brazil. Ethnographic research has demonstrated that when cattle dominate rural landscapes, this can influence cultural

identities, and foster negative views about forests (Hoelle, 2015, 2018; Hoelle, Gould and Tauro, 2022). Taken with the previous highs in Amazonian culture affiliation in the early frontier, these dynamics could suggest that the trajectory of cultural expression can shift rapidly once cattle ranching consolidates as the economic and symbolic foundation of local livelihoods. Indeed, the complex and layered geopolitical histories and the distinct cultural expression at each frontier stage would suggest that timing of exposure to external environmental pressures is likely a large factor in determining cultural expression of both rural and urban people across Amazonia.

Interestingly, in late frontier Paragominas, urban and rural residents showed reduced assimilation with either Amazonian or cattle culture, suggesting a tipping point as deforestation slows. This may support previous suggestions of how cultural systems may collapse when the underlying environmental characteristics that underpin identities and cultures are modified to the point that a major shift in livelihood strategies must occur (Fernández-Giménez *et al.*, 2017). Moreover, this result could indicate that while cattle culture experiences a relative boom when cattle production is high (and at the expense of both physical forests and cultural identities associated with forests), this pattern does not necessarily hold once peak productivity has passed. In Paragominas, much of the expansive deforestation activity occurred before 2008, when the municipality's landowning elites made the decision to prioritize mechanistic efficiency and agricultural intensification over increased forest clearing due to both environmental and political constraints, a strategy which saw them come off the federal deforestation 'red list' and become the first so-called Green Municipality in Brazil (Viana *et al.*, 2016). However, this newfound status was seemingly not accompanied by a resurgence in traditional peasant identities and the cultural expression associated with them in our results.

3.4.2 Migration status and cultural expression

Migration is fundamental to deforestation frontier dynamics and our data show that migrants from elsewhere in Brazil have not yet arrived in the pre- (Tefé) and early-frontier (Lábrea) contexts we studied. Albeit it is likely that such migrants are present in the cattle-dominated parts of Lábrea (see Supplementary Figure 3.1), far from our fieldwork in the urban centre and River Purus. We found that Amazon-born people have stronger (or at least, less weak) Amazonian cultural markers in São Félix and Paragominas than non-Amazonian

migrants. Non-Amazonians in those highly deforested contexts also held particularly high affinity towards cattle culture. Controlling for potential socio-demographic differences between migrants and the host population, this migrant effect remained significant for traditional Amazonian culture and weakly significant for cattle culture. Taken together with our findings that people in São Félix (rural especially) consistently showed higher affiliation with cattle culture, this suggests that the study-wide lows in Amazonian cultural markers in São Félix and the highs in cattle culture expression are partly driven by non-Amazonian residents. This is congruent with ethnographic research that outlines how migrants from outside of Amazonia play a central role in the diffusion of cattle culture to Amazonian farm-forest frontiers (Hoelle, 2011, 2014, 2015). These results support Kendal and Raymond *et al.'s* (2019) assertion that in-migration to a social-ecological system can lead to a shift in cultural values. In our study context, this may manifest in weakened preferences for things like enjoying 'pure' acai (which is generally bitter compared to acai eaten elsewhere in Brazil and internationally, which is almost ice-cream like), primarily eating regional foods, or even seeing those foods as essential to their diet, which were very prevalent in pre and early frontier stages. These cultural practices are fundamental forms of cultural expression to Amazonian peasant cultures (Nugent, 1997), and are (to varying degrees) representative of livelihoods that are typically at risk of cultural and physical (due to forest loss) replacement following the arrival of cattle to the frontier (Salisbury and Schmink, 2007).

Non-Amazonians migrants tended to prefer Sertanejo music, enjoying or wanting to attend a rodeo, and the regular use of clothing items associated with 'country' styles, such as cowboy hats, boots and a belt buckle. As we might expect, respondents who were born in other parts of Brazil (Supplementary Table 3.4) participate more in the cultural expression of cattle culture than do locally born Amazonians (Hoelle, 2014). Yet, importantly, Amazonians in the deforested places we studied also demonstrated strong markers of cattle culture. This is congruent with the well-established idea that the local environment in which a person is raised is critical for the development of cultural norms and identities (Geertz, 1995). Yet, due to the study design, which relied on space-for-time substitution, we cannot make clear inferences on how the cultural values of non-Amazonian migrants and Amazonian-born people may become more similar over time as migrants become increasingly embedded and assimilated into the regional sub-culture (Stewart *et al.*, 2019).

Our results on the whole point to the expansion of agri-*cultural* frontiers with forest loss. While the biophysical aspects of LULCC are well documented, the concept of frontiers includes demographic, *cultural*, political, social, and economic transitions (Hecht and Cockburn, 1989). Importantly, our results suggest that agricultural expansion not only involves the raising of animals and the cultivation of previously forested landscapes, but also the diffusion and assimilation of alternative, somewhat external shared practices, beliefs, knowledge, and values (Kendal and Raymond, 2019). Our results are consistent with literature that frames the in-migration of people from outside of Amazonia to frontier locations as central to this cultural shift (Hoelle, 2015).

Recent dynamics of farm-forest frontier transitions have shown how rubber-tapping and colonist communities have reduced their traditional economic practices of small-scale agriculture and extractivism, diversifying into and becoming more reliant on cattle (Hoelle, 2011). Our results may demonstrate how agricultural frontier advances are accompanied by the substitution of traditional Amazonian *forest* cultures for cattle-based identities, which, importantly, raises concerns about whether frontier populations with fundamentally different cultural values will meaningfully engage in formal forest conservation schemes — such as the territory-based sustainability model, which has been founded on the sustainable cultural practices of Indigenous and traditional peasant communities across Amazonia (Hecht *et al.*, 2024; Parry *et al.*, 2025). While frontier expansion stems from economic, political, institutional, and individual drivers that prioritize cattle (Pacheco and Poccard-Chapuis, 2012), feedbacks that erode traditional Amazonian cultural practices and promote cattle culture warrant closer examination over a variety of frontier contexts (Hodel et al. 2024).

3.4.3 Study Limitations

One methodological limitation of this study is the design of the survey tool, which looked to capture cultural expression across a broad range of rural and urban respondents in distinct frontier stages. This study attempts to add to the thin literature on cultural expression and patterns of environmental change (see **Chapter 2**). Studies that examine culture empirically through survey methods in the chosen study context are few and far between or have been studied in only one context in much depth (Hoelle, 2015, 2018). As such, the survey tool, while grounded in our in-depth understandings of cultural norms of traditional peasant communities, informed by the project team's Amazonian fieldwork experience, as well as

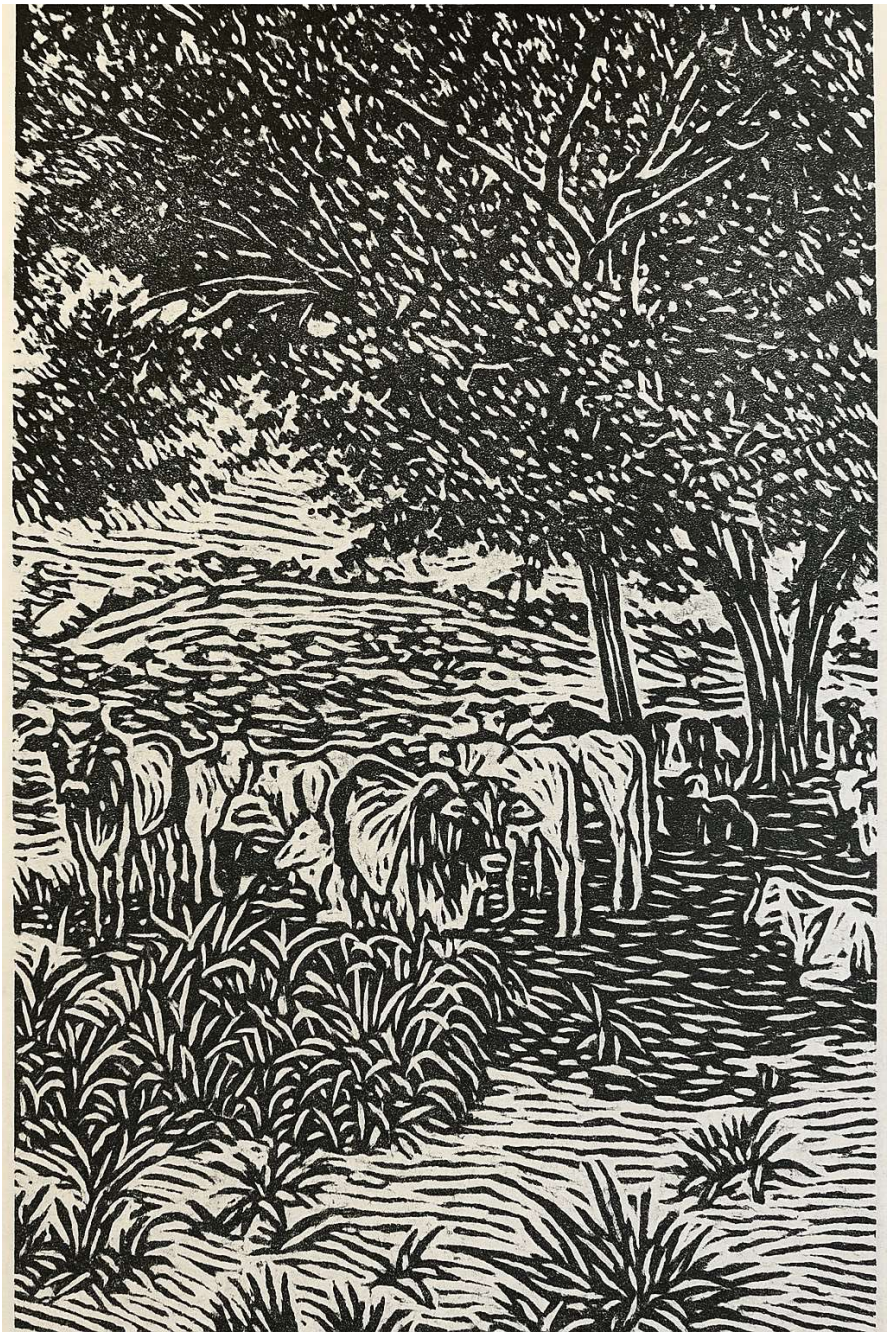
one member being from the Brazilian Amazon, the lead author's extensive fieldwork based in a leading agrarian studies department in Brazil (~ 1 year) and validated prior to data collection, was constructed from largely from scratch, while utilizing survey questions on cattle culture applied in a Western Amazonian frontier context (Hoelle, 2015, 2018). This was perhaps most problematic during the survey validation stage and subsequent factor groupings, where some of the survey items had low factor loadings in final CFA analysis. Although this is to be partly to be expected in crafting new survey tools, this meant a reduction in the number of survey items that were included in final analysis, with the minimum amount of items retained in the two final factors passed for later analysis. Secondly, study municipalities were selected in part due to existing community networks of co-investigators in the project team (LP, VG). Although this allowed for more fluid research activities in the field, this perhaps limited the types of land uses that this study would examine, and thus the breadth of cultural expressions being captured by survey responses. Finally, while every effort to ensure a representative sample was obtained for urban respondents, the constitution of rural surveys was dictated by a mixture of contact with relevant community leaders, prior informed consent from community representatives, ethical approval of lead and co-authors to visit particular reserve types in highly forested regions, and time and transport constraints of PI (JOL) during the field season. Furthermore, rural communities across our sample vary significantly in size and geographic context, meaning a somewhat uneven spread in sample size per community, despite efforts to sample as evenly as possible.

3.5 Conclusion

In this paper, we have demonstrated how cultural markers associated with traditional Amazonian forest cultures seemingly fade in response to an array of external drivers, including forest loss, conversion of land to pasture, and the in-migration of people from outside of Amazonia. This process seemingly results in the cultural substitution of forest cultures for cattle culture, a relatively new (in Amazonian terms) cultural identity(Hoelle, 2014), specifically when deforestation activity is high. Interestingly, the expression of cultural markers associated with both sub-cultures tails off in the late frontier stage of our sample, Paragominas. This would suggest that a cultural simplification occurs when rampant forest loss subsides and a large portion of the originally forested landscape has been simplified (Riechers *et al.*, 2020), or a 'boom', followed by a cultural 'bust', mirroring boom

and bust dynamics associated with human development indicators at frontiers in Brazil (Rodrigues *et al.*, 2009; Alencar, Parry and Melo, 2025). Importantly, our results not only point to this substitution effect, but may indicate a social-ecological tipping point once landscapes and cultures have been transformed (Fernández-Giménez *et al.*, 2017).

Our results demonstrate that deforestation and in-migration of people from outside of the Amazon is associated with the diffusion of cattle culture among urban and rural people in Amazonia, which is consistent with much of the current literature on the competing nature of cattle and forest cultural identities (Salisbury and Schmink, 2007; Gomes, Vadjunec and Perz, 2012; Hoelle, 2014). Culture is said to be a lens through which land-use decisions are made, impacting outcomes (Caldas *et al.*, 2015; le Polain de Waroux *et al.*, 2021). As such, cultural 'traps' with unsustainable outcomes may reduce the resilience and adaptability of social-ecological systems that had previously encouraged sustainable land-uses (Hodel, le Polain de Waroux and Garrett, 2024). This raises questions about how future interventions hoping to combat the progression of deforestation may be appropriate if the cultural lens through which rural actors view land-use strategies (primarily cattle, the protagonist of most deforestation in Amazonia) has already shifted to become more around cattle itself (Hoelle, Gould and Tauro, 2022). Conservation strategies should be culturally appropriate if they hope to achieve lasting impact (Ives *et al.*, 2024). They should ideally reflect the diversity of worldviews and lenses that decisions are made through (Garrett *et al.*, 2024) and be properly informed by the context in which they will be employed (Carmenta, Barlow, *et al.*, 2023). Future characterizations of the nature of LULCC in Amazonia should thus recognize that culture, while typically not regarded as an outright driver of land-use decisions, may serve to make achieving conservation outcomes more difficult, yet another force pulling in the wrong direction once frontier activity progresses. Recognizing this potential duality is therefore pivotal. Failing to do so may risk the loss of traditional Amazonian peasant cultural identities, cosmologies and livelihood strategies — foundations that have underpinned some of the most successful forest conservation reserves across Brazil.



"Gaps… call attention to the bad transportability of demarcations of human livelihood verses nature conservation, productive farms versus forest reserves, and settled culture versus the wild."

(Anna Lowenhaupt Tsing, Friction, 2005:175)

Chapter 4: Between cattle and canopy: Relational values in the Brazilian Amazon

Jordan O. Lafayette [1], Luke Parry [1], Christopher D. Ives [2], Jeffrey Hoelle [3], Carlos Valério Aguiar Gomes [4], Maria Raimunda da Silva Nascimento [5], Antônia Paula Vasconcelos Leite [6], Paulo Rigo Gomes Santos [7], Gustavo Roberto Coelho [6]

[1]Lancaster Environment Centre, Lancaster University, Lancaster, UK

[2]School of Geography, University of Nottingham, Nottingham, UK

[3]Department of Anthropology, University of California, Santa Barbara, CA, USA

[4]Amazonian Institute of Family Agriculture, Federal University of Pará, Belém, Brazil

[5] Federal Institute of Pará, Paragominas, Brazil

[6] Federal University of Amazonas, Manaus, Brazil

[7] Federal University of the South and South-East of Pará, São Félix do Xingu, Brazil

Chapter Acknowledgements

I would like to sincerely thank the Amazonian Institute of Family Agriculture for hosting me as a research student, especially the postgraduate program coordinator, Profa. Dr. Monique Medeiros, and the head of department, Prof. Dr. Luis Mauro Santos Silva. I would also like to thank the many community health agents (ACS) and secretariats of Lábrea, Tefé, Paragominas, and São Félix do Xingu, without whom data collection would have been implausible. Finally, I would like to thank the multiple professionals at local environmental and research organisations, such as Marcikely Santos at ASPACS in Lábrea, Heloisa Pereira at the Mamirauá Institute in Tefé, and Celma de Oliveira at Imaflora in São Félix, who provided much needed support and practical guidance, aid and research bases for rural data collection.

Author contributions

All authors contributed to the conceptualisation or active collection of this research. J.O.L performed the research with the help of G.R.C, M.R.N., P.G.S., and P.V.L.

J.O.L then wrote the first manuscript draft. J.O.L., L.P. and C.D.I. edited the current manuscript, while J.H. and C.V.G. provided comments throughout.

Abstract

Conservation science and practice are increasingly recognizing the importance of values in making sense of the diverse goals held by different actors and in guiding the effective implementation of conservation actions. While approaches to conservation have historically privileged a narrow set of values, recent contributions have highlighted how relational values could be a transformational and complementary tool for existing approaches to conservation policy. However, despite recent conceptual advances, relational values have typically been studied in abstracted ways. Further, empirical contributions are typically focussed on singular, particular places, limiting understanding of why relational values form and vary across different environmental contexts. Systematically comparing RVs across gradients of environmental change is therefore needed to uncover the mechanisms by which biophysical and social contexts shape these values, and to inform more effective, context-sensitive conservation policy. Comparing four frontier stages, characterised by variable recent deforestation intensity and historical primary forest loss in the Brazilian Amazon, we compare relational values towards both forests and cattle-dominated landscapes across rural and urban sub-populations. Structured questionnaires (n = 407) were conducted across both rural and urban populations. Factor analysis identified four emergent categories of relational values across our study area, namely forest identity & importance, forest utility, cattle-raising identity and importance, and cattle utility relational values. Relational value scores differed significantly across frontier stages and by urban and rural location. Both kinds of pro-forest values were higher in the pre and early frontier municipalities, and lower among intermediate and late frontier populations. Conversely, both pro-cattle factor scores were highest in intermediate frontier and lower among pre-frontier residents. Rural-urban differences in relational values were highly context specific, with the highest pro-forest values expressed by urban residents of Lábrea, while the highest pro-cattle and lowest pro-forest values were held by rural residents of São Félix do Xingu. Additionally, the composition of relational values was highly sensitive to local land-use context, with higher abundances of forest and pasture cover relative to other land-use types associated with stronger pro-forest and pro-cattle values respectively. This study contributes to the conceptualisation of relational values as a process that are constantly in flux, rather than static explanatory factors. We contribute to novel

understandings of how relational values evolve with landscapes, and are shaped by multiple interacting processes over time, rooting our findings in an empirical exploration of RVs with respect to frontier context, rural-urban settlement status, and local land-use strategies of rural people.

4.1 Introduction

Tropical land-use change is a major driver of global environmental change and biodiversity loss (Flores *et al.*, 2024). The Amazon rainforest is the most biodiverse ecosystem on the planet (Ribas *et al.*, 2025) and has supported human societies for tens of thousands of years (Heckenberger et al. 2018). One particularly destructive form of tropical land-use change is deforestation, with thousands of square kilometres of forest lost annually for consecutive decades in the Brazilian Legal Amazon (Austin *et al.*, 2017). Large-scale loss and degradation of primary forest across Amazonia since the 1970s has disrupted local ecological functioning and posed serious threats to biodiversity (Goebel *et al.*, 2025). Concurrently, this deforestation has underpinned the advance of agricultural frontiers, most notably through the expansion of cattle ranching (Filho *et al.*, 2021). Beyond ecological impacts, the ensuing social and economic transitions have diverse social consequences including increases in vector-borne diseases, parasitic infections and accelerated urbanisation of previously forested areas, leading to the displacement of forest dwelling peoples (Tallman *et al.*, 2022). Global climate agreements have repeatedly emphasised the importance of slowing tropical deforestation, especially in the most biodiverse ecosystems, such as the Amazon (Arima *et al.*, 2014; Fearnside and Filho, 2025). Importantly, although multiple political and economic interventions were implemented after 2005 to curb deforestation in Brazil's Legal Amazon, such as through federal monitoring and enforcement programs combined with market-oriented measures, these gains proved difficult to sustain (Godar *et al.*, 2014). By the start of the 2020s, shifts in political priorities and renewed pressure from global commodity markets contributed to a return of deforestation rates above 11,088 km² (de Area Leão Pereira *et al.*, 2020; Silva Junior *et al.*, 2020). While these patterns of land-use change and forest loss have been well studied over recent decades, the inconsistent outcomes of forest conservation across Amazonia underscore the need to understand a broader variety of the drivers of land-use change, including human culture and values.

Environmental research has increasingly foregrounded human values for nature, culminating in global syntheses such as the IPBES Values Assessment (2022), which highlighted the

diverse ways in which people perceive and benefit from ecosystems (Anderson *et al.*, 2022; Pascual *et al.*, 2023). Historically, approaches to biodiversity conservation have emphasized a narrow set of values, often privileging either intrinsic or utilitarian perspectives on nature and its contributions to people (Batavia and Nelson, 2017; Lele, 2023; Raymond *et al.*, 2023). Environmental economics further operationalized this focus by assigning monetary values to nature through the concept of ecosystem services (Costanza *et al.*, 1997). Building on this foundation, recent work has increasingly considered values in a relational manner, emphasizing how social, cultural, and identity-based relationships with nature shape environmental outcomes and can support transformative change (Chan *et al.*, 2016; Pascual *et al.*, 2017; IPBES, 2024). The concept of cultural ecosystem services has been particularly influential in linking multiple value types to practical conservation strategies (Chan *et al.*, 2020). Contributions from across disciplines, including sustainability science (Kendal and Raymond, 2019; Carmenta, Zaehringer, *et al.*, 2023; Ives *et al.*, 2024), ecological economics (Chan, Gould and Pascual, 2018; Kenter *et al.*, 2025), human geography (Szaboova, Brown and Fisher, 2020; Virtanen *et al.*, 2025), and anthropology (Hoelle, 2011, 2014, 2018; Hoelle, Gould and Tauro, 2022), have emphasized that relationality is central to understanding environmental research and policy (Lengieza and Aviste, 2025). Despite this growing recognition, the role of culture, values, and identity in shaping land-use and land-cover change (LULCC) remains understudied in mainstream conservation research (le Polain de Waroux *et al.*, 2021). To address this gap, much recent environmental sustainability research has focused on relational values (RVs hereafter), a subset of the broader relational turn, which emphasizes the interconnections between people and nature and the ways these relationships can inform sustainable management and policy (West *et al.*, 2020, 2024).

Relational values (RVs) are defined as meaningful and at times reciprocal relationships with the more-than-human world, such as a landscape or particular species (Arias-Arévalo *et al.*, 2018)(Figure 4.1). Unlike instrumental values, which view nature as a means to an end, or intrinsic values, which see nature as valuable in itself, RVs emphasize the ways humans relate to and care for the more-than-human world. Although historically under-recognized compared to economic or scientific measures of value, RVs are increasingly acknowledged as important for conservation, sustainability, and human well-being (Himes and Muraca, 2018). International agreements such as the Kunming-Montreal Global Biodiversity Framework highlight the need to integrate multiple values of nature into decision-making, and RVs are particularly well-suited to contribute because of their inclusive and relational perspective

(Pascual *et al.*, 2023; Raymond *et al.*, 2023). RVs can overlap with both instrumental and intrinsic values and are expressed in a variety of ways, including meaningful relationships, community bonding, care, identity, sense of place, and contributions to a "good life" (Chan *et al.*, 2016; Himes *et al.*, 2024).

Figure 4.1. Examples of environmental contexts across Amazonia in which relational values may be formed through reciprocal and meaningful relationships, community bonding, care, identity, sense of place, and other aspects that contribute to a "good life". *These examples include rivers and lakes (top left and bottom left); floodable forests and wetlands (such as mangroves; top centre); Terra firme (upland) forests, which typically support important trees and palms (e.g.Açaí palm, top right); and cattle-pasture (bottom centre). Images generated below were designed by Freepik (2025) (https://www.freepik.com/), with the exception of bottom left, which was taken by the lead author (JOL) on rural fieldwork, 2025.*

Although RVs are conceptually distinct from instrumental and intrinsic values, Himes *et al.* (2024) outline the overlapping nature of these three values categories (Figure 4.2). Relational, instrumental and intrinsic values can be broken down into articulations or expressions of values for nature, each encompassing diverse yet interrelated expressions of why nature matters to people (Klain *et al.,* 2017). While RVs are defined as meaningful and reciprocal relationships between humans and nature, they can also encompass expressions of values which are thought to be instrumental (such as the value of total fish harvested from a nearby river to a fisherman) or intrinsic (appreciating the sense of harmony that fish swimming

downstream). As such, utility value is conceptualised as an expression of RVs by Himes *et al.* (2024) and others (see Deplazes-Zemp & Chapman, 2021; Hoelle *et al.*, 2022 for example), despite generally being employed as a tool to demonstrate the economic losses associated with climate change and ecological degradation (Lele, 2023). This hints at the potential to utilise both RVs and instrumental expressions of utility value — such as the value of bushmeat harvested from nearby forest for both its' material (monetary, nutritional) and emotive (wellbeing, community/family tradition) importance to a family living in rural zone of a densely forested Amazonian municipality — in tandem to demonstrate why nature matters to people. The ability to combine empirical evidence pointing to the coexistence of both value expressions in this example would presumably be particularly powerful in advancing the values literature.

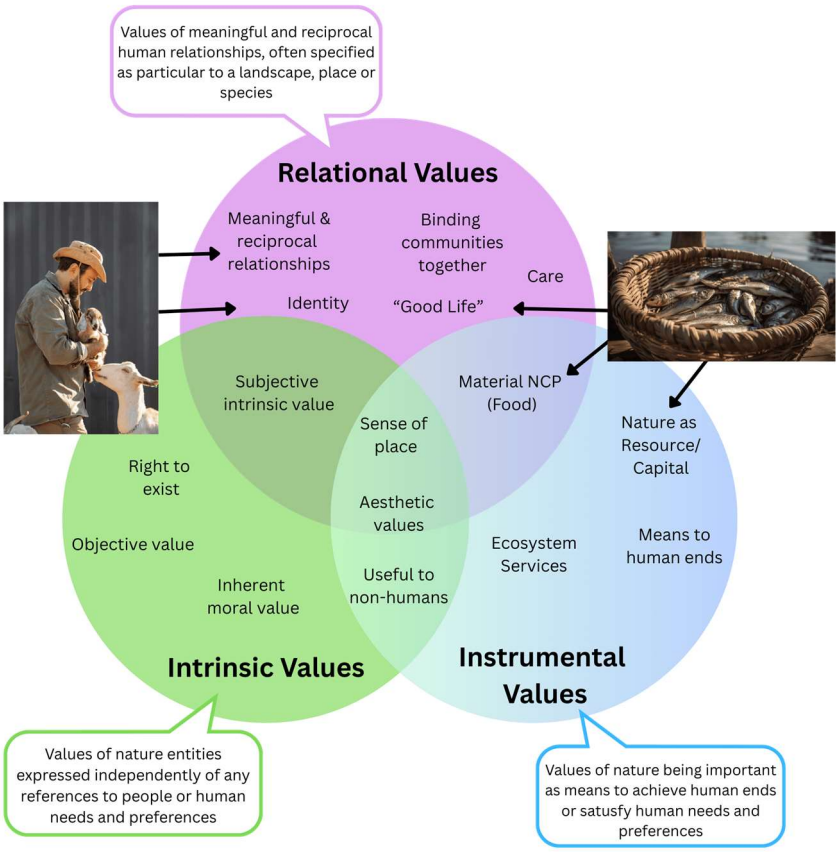


Figure 4.2. Environmental values expressions (shared across three categories of values [relational, intrinsic and instrumental values]), adapted from Figure 5, Himes et al. (2024), p. 33. *Example images are provided to illustrate how individual actions (such as rearing a young calf) can constitute an expression of multiple RVs, or how the value provided by fishing can be deemed expressions of both RVs and instrumental values in tandem, such as utility (Material Natures Contributions to People) through providing food for rural families.*

The RVs literature currently lacks sufficient empirical contributions that could help to facilitate neater integration with global conservation agendas. Relational values can represent both a congruent or alternative method to bring the non-monetary, emotive importance of nature into conservation and sustainability planning (Kleespies and Dierkes, 2020). They may also help to partly predict pro-environmental outcomes (Lengieza and Aviste, 2025). Yet, much of the forest conservation discourse is still shaped by environmental economics, which emphasizes ecosystems' role in planetary health and the financial costs of habitat loss (du Bray *et al.*, 2019). Conversely, limited empirical research has examined the composition of RVs across a variety of environmental contexts and among marginalized populations (Schulz and Martin-Ortega, 2018). Although some efforts have been made to validate the theoretical assumptions underpinning RVs through quantitative approaches (Klain *et al.*, 2017; Kleespies and Dierkes, 2020), their empirical foundations remain narrow. Much of the psychological research informing these assumptions has been conducted in W.E.I.R.D (*Western, Educated, Industrialised, Rich and Democratic*) contexts (Gould, Jimenez Naranjo and Balvanera, 2025), even as recent international policy reports and assessments attempt to ground RVs in concepts drawn from Indigenous and traditional ontologies (Anderson *et al.*, 2022; IPBES, 2024).

Strengthening empirical research on how RVs are formed and how they shift in response to environmental stressors (particularly in rapidly changing social-ecological contexts such as tropical forest regions undergoing extensive deforestation) will be essential if RVs are to play a meaningful role in shaping conservation discourse and practice moving forward.

4.1.1 Complexity of relational values

Relational values (RVs) and their role in shaping environmental change remain poorly understood, particularly in Global South contexts. While environmental values literature increasingly acknowledges the ways Indigenous Peoples and Local Communities conceptualize nature differently from Eurocentric models (Kenter *et al.*, 2025), in-depth empirical studies of these perspectives remain scarce (Virtanen *et al.*, 2025). Concepts such as *buen vivir* in Latin America illustrate the multi-faceted nature of relationships between nature, culture, and wellbeing, even attaining constitutional recognition in Bolivia and Ecuador (Beling *et al.*, 2018). However, RVs have often been framed as straightforwardly aligned with biodiversity conservation, despite evidence that they can also emerge in contexts

that support land uses considered environmentally harmful. For example, emotional and cultural bonds can form with cattle, pastures, and landscapes that underpin livelihoods and rural identities (Hoelle, Gould and Tauro, 2022), highlighting the complexity and sometimes contradictory nature of RVs (Maller, 2021). RVs are often presented as a complementary framework alongside instrumental and intrinsic values to articulate nature's importance (Horcea-Milcu *et al.*, 2023). Yet their complexity, and the ways in which they may, in some contexts, conflict with or complicate conservation objectives, remains poorly understood. This highlights a limited understanding of how RVs as a concept apply across different geographic and cultural contexts, leaving it unclear whether the frameworks developed to date are meaningful or relevant in places such as the Brazilian Amazon (Himes *et al.*, 2025).

Despite the rich and growing theoretical literature on RVs, to our knowledge they have only previously been studied empirically in singular particular places, or in deeply abstracted ways (Lengieza, Aviste and Richardson, 2023). One important omission from RVs literature is research that systematically compares the particular RVs across a gradient of environmental change. The Brazilian Amazon has undergone rapid change through deforestation in recent decades, with up to 70% of deforested land being used for cattle ranching (Filho *et al.*, 2021). The resulting spatial and temporal variation in forest cover across the Brazilian Amazon establishes a mosaic of ecological and socio-economic conditions (Schmink, 2019), providing a natural gradient to examine how RVs emerge, adapt, or interact with land-use practices such as cattle ranching. Using a political ecology lens, we can understand rapid and violent land-use change in our study context through the concept of frontiers (Guyot, 2011). Frontiers can be understood as a violent process of displacement of peasants, often by more powerful groups in favour of the growth of agro-industry, that not only include the biophysical aspects of land-use change, but also demographic, cultural, political, social, and economic shifts and transitions (Hecht and Cockburn, 1989; Thaler, Viana and Toni, 2019). Additionally, Schmink and Wood (1992) outline a frontier to be characterised by a diversity of actors that come together to contest land-use strategies. Frontiers can differ in intensity and context while being related, and are not only about resource extraction, but competing visions of a desirable future (Schmink and Wood, 1992), which can then decide the trajectory of environmental change in a frontier (Thaler, 2024). Frontier progression may thus be described as a battle of ideologies borne of dominant land-use strategies, political institutions and cultural narratives (Arima *et al.*, 2016). In contrast to pro-development visions that push the agricultural frontier, traditional and Indigenous populations have long managed forests and rivers sustainably, both

before the surge of cattle expansion in the 1980s and today within protected territories (Kröger, 2020). These territory-based sustainability practices are deeply organized and have significantly influenced environmental policy in Brazil (Hecht *et al.*, 2024). In regions such as Lábrea and Tefé (Amazonas State), these sustainable approaches are a key reason why substantial forest cover remains, despite broader pressures from agricultural expansion, resource extraction, and market forces (Parry *et al.*, 2025). Taken together, these frontier dynamics highlight that, while RVs provide a valuable theoretical lens, their empirical study must contend with complex, place-specific social-ecological processes shaped by both development pressures and long-standing sustainable practices.

4.1.2 Key knowledge gaps around relational values

Important research gaps remain in understanding how contested land-use ideals and their consequences for the environment shape RVs. While some studies have shown that RVs can become simplified within particular landscapes (Riechers *et al.*, 2020) or even be fostered in support of unsustainable land uses such as cattle ranching (Hoelle, Gould and Tauro, 2022), these dynamics have yet to be examined systematically across diverse social-ecological contexts. Importantly, such contributions would improve the flexibility of current narratives around RVs as a potentially transformative tool for sustainability (Chan *et al.*, 2020). For example, Mikołajczak *et al.* (2021) found no evidence that forest cover within 500 m of surveyed households along the Trans-Amazon Highway was independently related to emotional or cognitive connections to nature, or to ecological knowledge; instead, social factors played a far stronger role in shaping these relationships. This underscores the need to examine RVs within the broader social and political contexts in which they arise. At present, the RVs literature lacks nuanced, in-depth understanding of how RVs change in contexts with varied social and political dynamics undergoing environmental change. Examining RVs across frontier landscapes provides an opportunity to assess their applicability for conservation planning. While relational perspectives are recognized as valuable and potentially impactful for conservation (West *et al.*, 2024; Gould, Jimenez Naranjo and Balvanera, 2025), it remains unclear how RVs vary across space and in response to diverse environmental conditions.

Land-use change at tropical deforestation frontiers unfolds across both deforested and forested landscapes and reflects the values, relationships, and decisions of rural and urban

communities (Brondizio, 2025), making it a critical context for understanding how RVs influence environmental outcomes. Amazonia has been urbanized for decades (Parry, Barlow and Pereira, 2014), and most Amazonians are urban residents (Costa and Brondízio, 2009; Guedes, Costa and Brondízio, 2009). Rural-urban mobilities across Amazonia are longstanding, with traditional communities moving frequently between multisided rural and urban dwellings (Peluso, 2015). Furthermore, most rural Amazonians now tend to live relatively close to urban centres due to out-migration from remote headwaters, intensifying land-use change in peri-urban areas (Parry *et al.*, 2010). RVs are influenced by land-use change and the relationships that people have with different kinds of landscapes (Kendal and Raymond, 2019; Gould, Martinez and Hoelting, 2023). Yet, despite their influence on land-use decisions and environmental politics, the environmental views, attitudes, and actions of urban populations in Amazonia have largely been overlooked by research, which has historically focused on rural populations. Urban communities play a significant role in shaping environmental attitudes and practices. While some broad overlaps exist between rural and urban populations - for example, in food preferences and consumption of wild meat (Carignano Torres, Morsello and Parry, 2022) - important differences remain, such as the timing of exposure to these foods during childhood (Carignano Torres *et al.*, 2022), or more general reduced access to these foods accompanying urbanization trends (Chaves *et al.*, 2024). Further, urban populations are important in shaping the environmental and developmentalist politics at local scales, and commonly, most power and capital are accumulated in urban areas (Guedes, Costa and Brondízio, 2009). Indeed, the rural elite in Amazonian frontier municipalities often live in towns, where they may have other business and political interests (Viana *et al.*, 2016), despite being active and noteworthy contributors to rural land-use change. These details underscore that examining RVs in Amazonia cannot focus solely on rural populations; urban residents, their movements, and their distinct environmental perspectives are equally central to shaping land-use and conservation outcomes.

This study addresses three key gaps in the RVs literature to date. First, it foregrounds RVs in the Global South, where they have rarely been empirically investigated. Second, it examines the messier, context-dependent nature of RVs, acknowledging that strong relational bonds can sometimes be associated with land uses that challenge biodiversity objectives. Third, it bridges existing approaches by combining place-based specificity with the search for broader, generalizable patterns, allowing for a nuanced understanding of how RVs operate across

landscapes and communities while retaining analytical coherence. To address these gaps, this study investigates how RVs for both forested and non-forest landscapes are expressed by local populations across different deforestation frontier contexts in the Brazilian Amazon. It also explores the influence of rural versus urban locations on RVs, such as differences between urban and rural dwelling sub-populations in the same agricultural frontier context, or across areas of varying forest and pasture cover. The concept of frontier stages is employed to provide a structured framework for comparing RVs across environmental contexts. These stages represent distinct movements of frontier advance, and in this study, we adopt a space-for-time substitution, using spatial variation in the present day as an analogue for temporal changes in deforestation intensity and cumulative forest loss since remotely sensed deforestation data became available in 1986. Four municipalities across the states of Amazonas and Pará, Brazil, were selected to capture variation in current deforestation rates and primary forest cover. Each municipality has a distinct environmental history, shaped by varying trajectories of forest loss, cattle expansion, rural livelihoods, and the establishment of protected areas, providing diverse contexts to examine how RVs respond to environmental change. These contexts were prioritized in site selection because frontier theory highlights that environmental change unfolds non-linearly and is shaped by complex socio-ecological histories (Hecht and Cockburn, 1989; Schmink and Wood, 1992; Browder and Godfrey, 1997; Little, 2001; Thaler, 2024), suggesting that RVs are likely to vary across municipalities with different deforestation and land-use trajectories. Building on this framework, the present study aims to understand how RVs change across stages of agricultural frontier advance in the Brazilian Amazon, and we ask the following research questions (RQs):

1. How do relational values change across deforestation frontiers?

2. Do rural and urban sub-populations have distinct relational values?

3. How are relational values of rural people related to the local environment and land-use?

4.2 Methods

4.2.1 Study Area

To ensure that our data captured a diversity of frontier stages at both the meso-scale (municipalities with different levels of remaining forest cover, recent deforestation rates, and cattle herd size) and micro-scale (within each municipality we sampled from urban areas, and a diversity of rural locations with varying forest cover, pasture and agricultural land-uses), four Amazonian municipalities were selected based on some key criteria. First, all 772 municipalities in the Brazilian Legal Amazon were classified into quartiles of cumulative forest loss in 2023 as a proportion of original primary forest (from 1986). In order to select one municipality for fieldwork from each quartile, municipalities were shortlisted based on recent rate of deforestation and head of cattle (IBGE, 2016). Final decisions were based on whether the project team had any contacts or ongoing project activities in those municipalities. Where more than one municipality was suitable per quartile, the diversity of rural farm-forest landscapes and land uses within other municipalities influenced the final decision (i.e. to fit characteristics we considered typical for a given frontier stage). Deforestation frontiers were classified as ‘pre’, ‘early’, ‘intermediate’ and ‘late’, a total of four classifications. Deforestation and primary forest cover data were acquired from MapBiomas (https://brasil.mapbiomas.org/estatisticas/). Further information regarding deforestation classifications, such as exact rates of deforestation between 2020-2023, and the theoretical underpinnings of capturing the non-linear nature of frontier advance across Amazonia can be found in section **3.2.1 (Study Area), Chapter 3**.

For data collection in selected municipalities (Lábrea and Tefé, Amazonas State; São Félix do Xingu and Paragominas, Pará State), we aimed to capture representation from the whole municipal population, in order to answer the core research questions. As such, sampling efforts focused on a detailed and representative urban data collection strategy (Figure 3.4). Rural sampling locations within each municipality were selected purposively to capture the perspectives of dominant rural actors in contemporary frontier dynamics, rather than to represent the full spectrum of rural diversity. For example, this meant focusing on smallholders and cattle producers in areas where land-use decisions are most directly shaping forest conversion, such as in the intermediate frontier municipality chosen for this study, São Félix (Figure 3.3). We aimed to capture variation in rural livelihoods and settlement types

(e.g., long-established communities, agrarian reform settlements) while ensuring comparability across municipalities in terms of their relevance to deforestation processes. Importantly, we did not sample within Indigenous territories, as these groups were outside the scope of this study and their land governance regimes differ markedly from those driving most local deforestation. A limited number of interviews were conducted within formally recognized sustainable-use reserves, primarily in the early frontier municipality of Lábrea. This decision was taken because extractive reserve households represent an important segment of rural populations in such municipalities and excluding them entirely would have overlooked a significant rural actor in these contexts. At the same time, we sought to avoid over-representing reserve populations, instead prioritizing a broader diversity of rural actors that engaged with dominant modes of production in each municipality selected for this study, as well as the logistical hurdles that working solely in extractive reserves present. Within each municipality, sampling sites were identified through a combination of prior literature, consultations with colleagues and students at the Federal University of Pará (UFPA), and field knowledge provided by the co-supervisor (VG) of the lead author (JOL) during his doctoral studies based at UFPA. This collaborative process helped refine site selection to ensure both scientific relevance and feasibility for fieldwork by a visiting PhD student.

The four selected municipalities differed markedly in terms of recent rates of deforestation, primary forest cover remaining, head of cattle and total pasture cover (Table 3.1). Additionally, sampled municipalities were diverse in terms of geographic area, population size, formal education, among other things, and they each have distinct political, economic and environmental histories. In other words, inevitably the four municipalities are diverse in many senses (as are any case study locations), and not just in relation to their deforestation frontier stage. For this reason, whilst they provide insights into environmental RVs in different frontier contexts, the empirical findings from this study are not necessarily generalizable to other frontier situations.

A detailed account of each municipality's environmental contexts, unique environmental and geopolitical histories, and key statistics (such as municipality size, remaining forest cover, proportion of land deforested, percentage of rural vs urban residents, and head of cattle) has been provided in sections **3.2.1 (Study Area)** and **3.2.1.1 (Environmental Histories)** in **Chapter 3**. Refer to these sections for any additional context needed for later sections of this chapter, including tables (such as Table 3.1) or study area maps (Figure 3.3 or Figure 3.4).

4.2.2 Data Sampling

Data sampling effort was split between urban and rural areas, proportional to the urbanization level of each municipality. Each municipality differed greatly in area, population size (size and demographics), total urbanized area and proportion of rural-urban residents (Table 3.2). Urban areas varied in their geographic area (from ~6km² - 29km²) and population sizes (from 30,871 to 91,938). All municipal populations in this study were mainly urban (ranging from 68% to 87%).

Urban sampling was randomized and intended to capture RVs that were representative of the urban population. Conversely, rural sampling aimed to capture representation from a diversity of rural producers with respect to the dominant modes of production and identity categories within each municipality. As such, rural sampling was designed to capture perspectives from people living in representative landscapes from each municipality (in other words, in the highly forested pre-frontier was sampled mainly from traditional forest communities whereas in the cattle-dominated late frontier we sampled mainly from largely-deforested properties in which there was significant pasture and cattle), andwith varying degrees of distance from the urban centre. The latter was in order to avoid a potential geographic bias in terms of remoteness from people's environmental RVs. Data sampling also aimed to conduct interviews with interviewees across social groups with varying degrees of relative power in land-use recognition and decision-making at local and municipal levels. As such, data collected included some interviewees that self-identified as *Riberinho*, *Agricultura Familiar*, or descending from Indigenous or *Caboclo* communities. Importantly, Indigenous communities residing in Indigenous reserves were omitted from data collection efforts, due to the ethical constraints of obtaining permission as a foreign researcher within the allotted fieldwork time (~ 4 months), and the distinct worldviews and cosmologies that indigenous peoples have developed over millennia, which are distinct from those of many traditional peasant communities that this study was designed to examine. Additional details on the exact urban and rural sampling methodology followed are provided in **Sections 3.2.2.1 (Urban Sampling)** and **3.2.2.2 (Rural Sampling)**, respectively, in **Chapter 3**.

4.2.3 Survey Instrument

The survey tool (a structured questionnaire) was administered during a face-to-face interview lasting approximately 25 minutes. The survey was composed of three sections: *socio-*

demographic characteristics and identity; cultural expression; and *environmental relational values.* Survey questions were nested in a comprehensive classification of RVs expressions provided by Himes *et al.* (2024). Survey items drew on previous qualitative and quantitative studies in similar Amazonian frontier contexts from tangential fields such as environmental anthropology (Hoelle, 2015, 2018), environmental psychology (Mikołajczak *et al.* 2021, 2023), as well as previous studies which focused on use and non-use values of forests perceived by Amazonian communities (Carignano Torres *et al.*, 2016). Further, we adapted questions from other surveys which utilised RVs in other contexts (Uehara, Sakurai and Tsuge, 2020), capitalising on the project team's extensive experience of working in the Brazilian Amazon (in addition to one of the primary contributors being from the Brazilian Amazon) and understanding of RVs literature to reframe these questions to fit our rural Amazonian study context. When designing survey questions, we aimed to examine the continuum of RVs associated with both forest-based livelihoods and cattle-pasture expansion, with an emphasis placed on capturing positive relational values associated with cattle as well as forests (see Hoelle, 2018; Hoelle, Gould and Tauro, 2022).

An initial scoping of all relevant survey instruments was conducted by JOL across RVs literature and literature deemed to be RVs adjacent by the project team (such as environmental psychology and environmental anthropology). A final list was compiled by JOL, with all relevant questions mapped against a RVs expression (see Himes *et al.,* 2024) by JOL and LP. Questions were then rephrased by the project team to fit more closely with the key research questions of the project. An initial survey instrument that had a minimum of 2 questions per RV expression was created by JOL and LP, and then refined through numerous project meetings with other contributing authors (CI, JH, VG, KM). A further refinement was made before piloting the study, which was to split the questions by their relation to individual landscape types i.e. some questions asking about RVs for forested landscapes and others about cattle/pasture landscapes, and some comparative questions. Finally, a total of 21 pilot surveys were conducted. These surveys were conducted largely on campus grounds of the Universidade Federal do Pará (UFPA), Belém with visiting Family Agriculture students who were mostly from rural communities (e.g. small-scale family agricultural producers), and students from rural areas in other parts of Amazonia (e.g. Maranhão). These initial surveys aided in the refinement of survey question wording, the order of questions asked, and finally, understanding whether the survey had an initial statistical validity. Following these

interviews, Cronbach's alpha test revealed the internal validity of the final 27 RVs questions to be 'acceptable' ($\boldsymbol{\alpha} = 0.72$).

4.2.4 Survey Validity

The RVs scale must be consistently repeatable in order to give similar results for different observers under similar circumstances (sense Bland and Altman, 2002). Due to the novel nature of the RVs survey instrument – derived from multiple other scales and adjusted to fit the study context and research aims – the internal validity of the scale was checked. Further, Omega analysis was conducted to understand whether the newly constructed survey tool accurately captured the multi-dimensional nature of RVs (Kleespies and Dierkes, 2020), or whether the questions collectively related to a singular construct. All analysis was conducted in R Studio 4.5.0.

Survey items were developed to represent two *a priori* sub-categories or sub-scales: (i) Pro-forest; and (ii) Pro-cattle. Across 27 total questions, 15 were included in the pro-forest sub-scale and 10 were included in the pro-cattle sub-scale, and 2 items were removed because of ambiguity in question wording that did not fit neatly in either category. The internal validity of *each* RVs subscale, or the extent to which the selected survey items measured a common underlying construct, was then separately tested. Although Cronbach's alpha is a generally accepted tool for assessing underlying scale coherence, the Omega statistic (ω) generally performs better in assessing the unidimensionality of a scale (Zinbarg *et al.*, 2005). The survey tools included multidirectional likert scale questions, where 1 = 'completely disagree', and 5 = 'completely agree' with the statement (Supplementary Table 4.1).

The two-factor omega models for each subscale demonstrated a moderate saturation on an underlying construct, or 'g' (pro-forest $\omega_h = 0.61$; pro-cattle $\omega_h = 0.5$), indicating that both scales, while demonstrating a moderate general factor, are likely to have distinct sub-factors that measure distinct but related themes within a construct (Supplementary Figure 1 & Figure 2). The pro-forest subscale was more unidimensionally cohesive, and the pro-cattle subscale was more likely to comprise related but distinct themes, just reaching the acceptable unidimensionality threshold of 0.5 for ω_h. The internal validity of both scales was strong (pro-forest $\omega_t = 0.83$; pro-attle $\omega_t = 0.81$), suggesting that the variance in the data was well-explained by all factors (g + F1, F2, F3). Based on these results, both models could conceivably be passed into an EFA to discern a factor structure for both subscales.

Confirmatory factor analysis (CFA) was conducted for both subscales using one-factor and multi-factor approaches. The omega results (Supplementary Figures 3.1 & 3.2) suggested that, while there was acceptable unidimensionality to each subscale, a multi-factor solution was justifiable, and consistent with previous CFA conducted in empirical studies of RVs (Kleespies and Dierkes, 2020) compared to a one-factor solution. All CFA tests were conducted using a Weighted Least Squares Mean and Variance adjusted (WLSMV) estimator method, because it is more appropriate for ordinal (e.g. Likert-style) data than a standard Maximum Likelihood (ML) estimation method, which relies on assumptions of distribution normality and non-kurtosis (DiStefano and Morgan, 2014).

4.2.4.1 Pro-forest subscale:

The initial one-factor CFA for the pro-forest subscale that included all 16 survey items returned the following fit indices: Robust CFI = 0.738, Robust TLI = 0.698, Robust RMSEA = 0.095, SRMR = 0.075. As such, the model fit was deemed poor, and the following items were removed from the model due to weaker (<0.5) factor loadings: Q2 (0.328), Q7 (0.469), Q15 (0.034), Q16 (0.487), Q17 (0.476), Q18 (0.332), Q19 (0.425), Q23 (0.478), Q26 (0.375). This left 7 items in the final CFA with 'strong' factor loadings (≥ 0.5) (Supplementary Table 4.2).

The two-factor CFA for PFRV retained 10 survey items with strong factor loadings, losing 6 items in total: Q1, Q7, Q15, Q18, Q19 & Q26. The model fit indices improved across the board, with marked improvements in the Robust RMSEA ('poor' to 'acceptable') and Robust CFI ('acceptable' to 'excellent'). The two factors reflected distinct but related sub-dimensions of forest-associated RVs ($r = 0.73$, $p < 0.001$), with all items being significantly linked to the same underlying general construct (Supplementary Figure 4.1). In summary, a two-factor pro-forest subscale was considered the most robust for use in statistical models.

4.2.4.2 Pro-cattle subscale:

The initial one-factor CFA for the pro-cattle subscale included all 10 survey items and returned the following fit indices: Robust CFI = 0.709, Robust TLI = 0.625, Robust RMSEA = 0.132, SRMR = 0.091. As such, the model fit was poor, and the following items were removed from the model due to weaker factor loadings: Q2 (0.420), Q20 (0.32), Q25 (0.35) & Q27 (0.39), leaving 6 items included in the final one-factor CFA with 'strong' factor loadings (≥ 0.5) (Supplementary Table 4.1). The three-factor CFA for PCRV failed to meet adequate standards of model fit requirements (supplementary table 2). A two-factor CFA

solution returned acceptable to good model fit results, with model fit indices improving consistently. After factor reduction, model fit was acceptable by robust indices (CFI = 0.95, TLI = 0.91, SRMR = 0.041). The robust RMSEA of 0.085 was slightly above threshold, but the model remained interpretable and well-identified conceptually. Again, factor covariance was strong ($r = 0.62$, $p < 0.001$), suggesting distinguishable yet related sub-constructs of a multi-dimensional cattle/pasture RVs scale (Supplementary Figure 4.1). In summary, a two-factor pro-cattle subscale was considered the most robust for use in statistical models.

4.2.4.3 Subscale factor composition:

Each subscale had two distinct yet related factors (Supplementary Tables 4.1 & 4.2; Supplementary Figure 4.5). For the pro-forest subscale, these questions were collectively interpreted as relating to (i) *Forest utility* - Likert-style scale survey questions which centred around the practicality and use value of the forest for local people (e.g. "Forest extractivism and family agriculture have a strong tradition here', and 'I prefer farmed fish to river fish"); and (ii) *Forest identity & importance* - Likert-style questions that outlined how forests underpin personal and communal identities ((e.g."The forest is an important part of my identity") and the forests' importance to daily life (e.g. a cooler micro-climate: "If it weren't for the forest close by I would have already died from the heat by now'). In our analysis, factor ii (*forest identity and importance*) included two items describing forests as providing refuge from regional heat, a function that could be interpreted as a utility value (Table 4.2). However, the factor analysis for these items loaded more strongly with items related to forest identity, suggesting that respondents associated this ecological function with their sense of place and cultural attachment to forests, rather than strictly practical benefits. Conversely, the *forest utility* factor captures items related to material and experiential benefits.

For the pro-cattle subscale the factors were named - (i) *Cattle utility* - questions related to the practical and use value of cattle and/or pasture (e.g. "I prefer to have a clear area around my house with little forest" and "It would be good if a large part of the Amazon rainforest were converted into productive agricultural land"); and (ii) *Cattle-raising identity & importance* - Likert-style questions drawing on the importance of cattle to local identities (e.g. "We have a strong tradition of cattle ranching here") and the importance of cattle and/or pasture to livelihoods (e.g. 'People that work on a ranch have the chance to connect with others' or 'Anyone that raises cattle can have a good quality of life'). CFA scores were then used as dependent variables in statistical modeling (e.g. robust linear modeling) to understand how

groups of pro-forest and pro-cattle RVs were associated with the four different frontier stages, urban and rural dwelling and finally, local forest cover (rural respondents only).

4.2.5 Data Analysis

All survey questions were Likert scale questions, ranging from complete agreement to complete disagreement with a statement (where 5 = completely agree, and 1 = completely disagree)(Table 4.1). Survey questions were not unidirectional in their measurement of RVs because they aimed to capture positive RVs for both forest and pasture, and thus were either favourable towards cattle/pasture/deforestation, or towards forests and nature. Thus, when splitting survey items into subscales, certain question responses were reverse coded using the 'dyplr' package in RStudio to assure directional consistency of survey responses for factor analysis.

Table 4.1. Relational environmental values factors representing pro-forest and pro-cattle values of utility and identity/importance. Following CFA, including factor names and questions included in each factor. Questions in italics * were reverse coded to maintain directional consistency in factor analysis.

Factor Name; Questions included (English); *Questions included (Portuguese)*
Forest Utility; Q3) Outsiders take the fish of river-dwellers; *Pessoas de fora roubam bastante os peixes dos ribeirinhos.* Q6) In the forest, communities have the chance to work together and do things together; *Na mata, nossas comunidades têm a oportunidade de se juntar, e conseguir fazer coisas juntas.* Q9) Working in the swidden plot or forest has more tradition here in this municipality than cattle-ranching; *Trabalhar na roça ou na floresta tem mais tradição em nosso município do que agropecuária.*

Q16) Farmed fish are better to eat than fish from the river*;

*Peixes de criação são melhores para comer do que peixes do rio.**

Q17) Bushmeat is delicious!;

Caça é gostosa.

Q21) A lunch without toasted manioc flour (*farinha*) isn't really a lunch; *Um almoço sem farinha não é um almoço de verdade.*

Forest Identity & Importance;

Q11) The forest is an important part of my identity;

Eu sinto que a floresta faz parte da minha identidade como um Labrense/Tefeense/São Felixense/Paragominense

Q14) The forest here is very important to me;

As florestas e águas da minha comunidade são muito importantes para mim.

Q22) If it weren't for the forest close by I would have already died from the heat by now;

Se não fosse pela floresta aqui perto, eu já teria morrido de calor.

Q23) The city is hotter now because there is less forest and more asphalt;

Na cidade está mais quente agora porque têm muito asfalto e pouca floresta perto.

Cattle Utility;

Q4) I would prefer to have a clear area around my house with little forest;

Eu prefiro ter uma área limpa ao redor da minha casa, sem mata.

Q5) I think that pasture is attractive;

Acho que pasto é bonito.

Q24) It would be good if a large part of the Amazon rainforest were converted into

productive agricultural land; *Seria bom se uma boa parte da floresta aqui na Amazônia fosse convertida em terras produtivas e.g. para plantar soja ou criar boi.*
Cattle Identity & Importance; Q8) We in this municipality have a strong tradition of agriculture and cattle ranching; *Nós Tefeenses/Labrenses/São Felixense/Paragominense temos uma tradição forte de agropecuária.* Q10) Someone that owns cattle can have a good quality of life; *Alguém pode ter uma boa qualidade de vida criando gado.* Q13) People living on ranches have the chance to connect with others; *Nas fazendas, as pessoas têm a oportunidade de se juntar e conseguir fazer coisas juntas.*

An initial nonparametric global Kruskal-Wallis test was conducted for each of the four RVs factor scores to assess overall differences whether relational value factors across frontier stages (RQ4.1). Following significant Kruskal-Wallis test results, we conducted pairwise comparisons using Dunn's post hoc tests with Bonferroni correction (Dunn, 1964) to identify which frontier stages differed significantly from each other. This nonparametric approach was selected to account for non-normal distributions of factor scores. To further explore the magnitude and direction of differences between frontier stages, estimated marginal means were calculated from linear regression models for each factor, allowing for adjusted comparisons that account for potential covariates. This combination of nonparametric testing and regression-based estimation provides a robust assessment of unadjusted group differences and insight into the adjust effects within the social-ecological context of each frontier.

Kruskal-Wallis nonparametric tests were conducted to test for differences between urban and rural interview respondents in their RVs composition (RQ4.2). This was first performed through a global Kruskal-Wallis test for overall differences between urban and rural respondent profiles and followed by repeated tests between urban and rural settlements within municipalities. Further, to understand the association between both frontier stage and

rural/urban dwelling and RVs composition, linear modelling was conducted. To account for potential violations of classical linear model assumptions, we employed robust linear models using M-estimation (Ronchetti and Huber, 2009). This approach provides more reliable coefficient estimates in the presence of heteroscedasticity and influential outliers, common features in observational and survey-based data collected in complex field settings such as the Amazon.

Forest cover around rural locations: Landscape characteristics around rural interview locations were calculated using ArcGIS Pro 3.1.0 (for RQ4.3). Land use and cover data was acquired from the MapBiomas platform (https://brasil.mapbiomas.org/colecoes-mapbiomas/). Land use and cover data was added to ArcGIS under spatial reference WGS 1984, extracted, and then projected (converted) to the South America Albers coordinate system for further analysis. Survey household coordinates were added as XY point data under WGS 1984 and then projected to South America Albers to enable spatial comparison with other acquired data from MapBiomas. This is because MapBiomas projections rely on conversion to a geographically appropriate coordinate system to show detailed land use data. Buffers of 1-km radius (3.14 km^2) were then applied per household. This radial distance was chosen because rural producers across Amazonia make use of large territories for farming and fishing with many rural people regularly passing through and helping on neighbours' lands (see Parry, Barlow and Peres, 2009; Piva da Silva, Fraser and Parry, 2022). Furthermore, this distance has been shown to best explain variation in the non-material value attributed to forests by Amazonian communities compared with larger distances (2-5km buffers) in previous studies (Carignano Torres *et al.*, 2016). These daily interactions that extend to land owned by neighbours were considered important in the study context by the project team because of the shared nature of RVs expressions e.g. 'binding communities together' (Himes *et al.,* 2024). Features were dissolved in ArcGIS by their individual reference number (survey reference), so that buffers for households within a 1-km distance of one another would not double count land-use types. A 'tabulate area' calculation was applied with acquired land cover data against each buffer. This returned a summary of the aerial coverage of forest and agricultural land-uses, as classified by MapBiomas, within the buffer around each surveyed household, named 'local area statistics' herein. Results were exported to a new excel file and imported to R 4.5.0 for further analysis.

A rural subset of all RV factor scores and relevant covariates was created and merged to the new local area statistics data. Correlation matrices were calculated using Spearman's rank

method, with Bonferroni corrections applied for multiple significance tests (Gauthier, 2001). To investigate how RVs for both forest and cattle relate to land use and land cover (LULC), LULC proportions within the 1km buffer (each buffer had an area of 3.1 square kilometres) per survey response household were treated as compositional data and isometric log-ratio (ILR) transformations were applied using compositional data analysis (CoDA) (Aitchson, 1986). This approach accounts for the constrained nature of proportion data and allows for interpretable contrasts between LULC categories (e.g., forest vs. pasture mosaics). Initially, several potential balances were considered, including:

(i) Forest formation relative to pasture cover; (ii) pasture relative to forest categories; and (iii) rivers, lakes, and oceans relative to other land-use types. However, exploratory correlation analyses indicated that pasture and forest cover are strongly negatively correlated in the rural buffers ($r = –0.82, p < 0.001$). As such, the effects of these land-cover types on relational values are almost mirror images (i.e. greater forest cover corresponds to stronger pro-forest RVs and weaker pro-cattle RVs, while greater pasture cover corresponds to stronger pro-cattle RVs and weaker pro-forest RVs)(Supplementary Figure 4.4). To simplify interpretation and align with theory, we modelled pro-forest RVs as a function of all forest formation within the buffer (*terra firme* and floodable forest) and pro-cattle RVs as a function of pasture, using ILR balances to account for the compositional nature of the land-use data. This approach captures the primary land-use contrasts driving relational values without redundancy. Additionally, although rivers, lakes, and oceans are positively correlated with pro-forest RVs (both $r \geq 0.37, p < 0.001$), we did not include them as a separate balance because they co-occur with forests ($r = 0.41, p < 0.001$) and including them would complicate interpretation without adding independent explanatory power. Furthermore, savanna formation was not included as a separate component in the ILR balances because it co-occurs with pasture ($r = 0.41, p < 0.001$). This approach captures the most salient and theoretically meaningful land-use opposition in the region (the replacement of forest by pasture for cattle ranching, which also has significant ecological impacts for rivers and lakes across Amazonia (see Castello and Macedo, 2016; Lathuillière *et al.*, 2019)), while avoiding issues of multicollinearity and unnecessary model complexity. ILR coordinates were then included as predictors in ordinary least squares (OLS) linear regression models to explain variation in responses to relational value constructs derived from survey data. Because rural interviews were clustered within only four municipalities, spatial regression models and mixed-effects models were not appropriate. Instead, to account for non-independence of

households within the same frontier stage, we estimated ordinary least squares models with standard errors clustered by frontier stage. This approach provides more robust inference given the small number of clustered rural samples (Cameron and Miller, 2011).

4.3 Results

RQ4.1) How do relational values change across deforestation frontiers?

Mean relational values factor scores varied significantly across frontier stages when considering the combined urban and rural samples (KW Forest utility: $\chi^2 = 205.59$; *Forest identity and importance*: $\chi^2 = 114.93$; *Cattle utility:* $\chi^2 = 90.365$; *Cattle identity and importance:* $\chi^2 = 22.429$, all $p < 0.001$)(Figure 4.4). Pro-forest RVs were significantly higher in early frontier Lábrea than the pre-frontier context of Tefé (*adj.* $p < 0.001$), while intermediate and late frontier contexts did not differ significantly (both *adj.* $p > 0.28$). Pro-cattle RVs were significantly higher in the intermediate frontier of São Félix do Xingu (both *adj.* $p < 0.001$), with the exception of cattle utility values, which were not significantly higher than the early frontier context ($p > 0.99$)(Supplementary Table 4.4). Cattle identity and importance values were higher in early frontier contexts than in pre-frontier settings (*adj.* $p < 0.001$), but not significantly different from the late frontier context of Paragominas (*adj.* $p > 0.99$).

Estimated marginal means (EMMeans) from models treating frontier stage as a categorical predictor also indicated that both pro-forest utility (0.423 ± 0.034, $p = < 0.001$) and pro-forest identity (0.454 ± 0.047, $p = < 0.001$) mean scores were highest in Lábrea, the early frontier stage (Table 4.3). Conversely, pro-forest factors were lowest (forest utility: -0.404 ± 0.036, $p = < 0.001$; forest identity: -0.308 ± 0.051, $p = < 0.001$) in São Félix do Xingu, the intermediate frontier stage. Perceived cattle utility ($0.167, \pm 0.052$, $p = < 0.01$) and cattle identity (0.311 ± 0.048, $p = < 0.001$) scores peaked in the intermediate frontier. The lowest factor scores for cattle utility (-0.135 ± 0.048, $p = < 0.01$) and cattle identity (-0.364 ± 0.044, $p = < 0.001$) were observed in pre-frontier Tefé.

When frontier stage was modelled as an ordered factor to assess a continuous trend, linear regression suggested a gradual decline from pre through late frontier stages in forest utility RVs factor scores ($\beta = -0.20$, $SE = 0.02$, $p < 0.001$) and forest identity ($\beta = -0.17$, $SE = 0.02$, $p < 0.001$)(Figure 4.3). An inverse relationship is suggested for pro-cattle identity RVs, with

scores gradually increasing as frontier stages progress ($\beta = 0.18$, $SE = 0.02$, $p < 0.001$). However, pro-cattle utility RVs factor scores showed no significant increase with the progression of frontier stage ($\beta = 0.03$, $SE = 0.02$, $p = 0.188$). Taken together, these results suggest that while pro-forest RVs tend to be higher in pre-frontier Tefé compared with late frontier Paragominas, the early-stage frontier Lábrea may represent a local high point in pro-forest values. Conversely, while mean cattle identity values are lower in Tefé compared with Paragominas, values were highest in intermediate stage São Félix do Xingu. Cattle utility values showed few significant differences between frontier stages but were significantly higher in São Félix do Xingu than other municipalities (Figure 4.3).

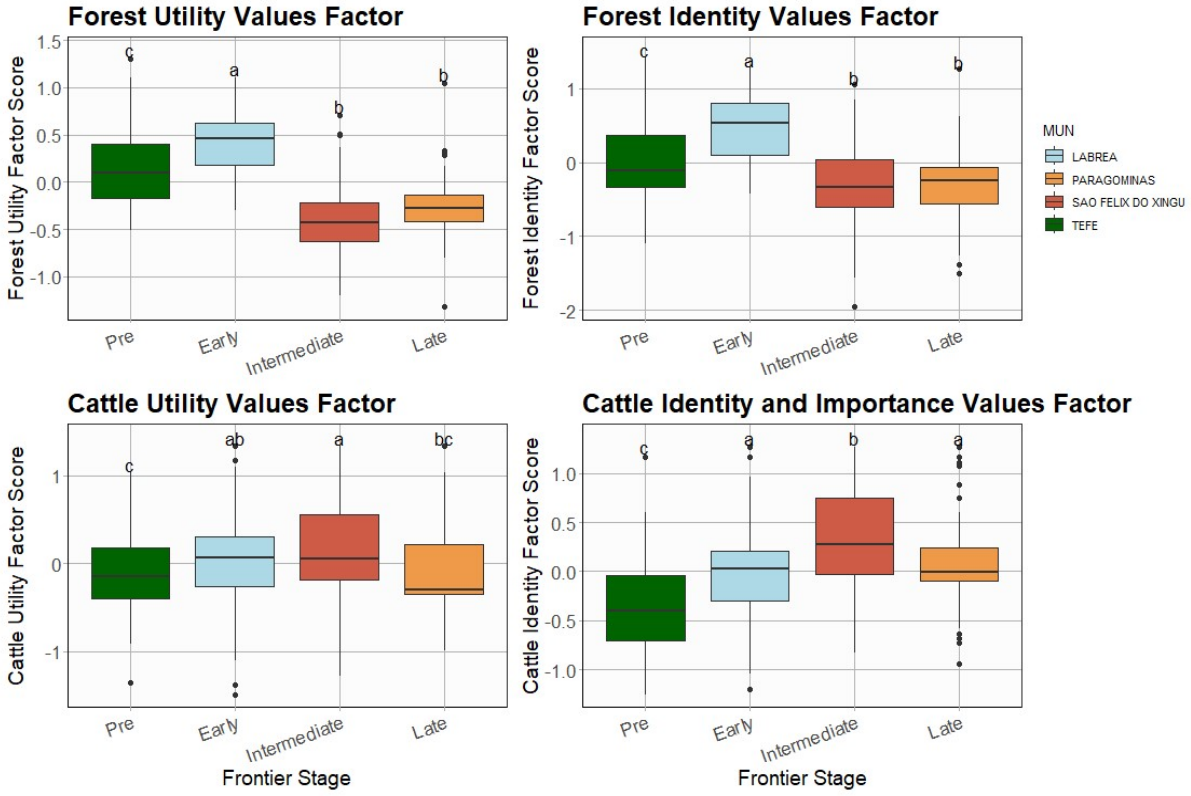


Figure 4.3. Boxplot of relational environmental values factor scores separated by deforestation frontier stage (as identified in table 3.4), colour coded by municipality). *Letters above each municipality box represent whether there is a significant difference in the distribution of factor scores by municipality (or frontier stage), based on Dunn's Tests for multiple pairwise comparisons (e.g. where two boxes with 'a' above indicate no significant difference between those two municipalities, but boxes with 'a' and 'b' respectively indicate significant differences between these municipalities.*

Table 4.2. Univariate linear model expected means for relational value factor scores per frontier stage and the standard error based on 95% confidence intervals.

Frontier Stage	Forest Utility Factor Score	Forest Identity Factor Score	Cattle Utility Factor Score	Cattle Importance and Identity Factor Score
Pre	0.147 (± 0.033)	0.049 (± 0.046)	-0.135 (± 0.048)	-0.364 (± 0.044)
Early	0.423 (± 0.034)	0.454 (± 0.047)	0.056 (± 0.049)	0.002 (± 0.044)
Intermediate	-0.404 (± 0.036)	-0.308 (± 0.051)	0.167 (± 0.052)	0.311 (± 0.048)
Late	-0.263 (± 0.033)	-0.291(± 0.051)	-0.085 (± 0.053)	0.096 (± 0.048)

RQ4.2) Do rural and urban populations have distinct relational values?

Urban and rural populations did not hold significantly different RVs towards forests or cattle when grouping all municipalities (n = 411) (Kruskal-Wallis; all $\chi^2 < 1.5$; *ps > 0.2*)(Supplementary Table 4.6). However, some differences in the RV factor scores between urban and rural populations were context-specific (Figure 4.4). Perceived forest utility scores was significantly lower among rural respondents compared to urban respondents in São Félix do Xingu (KW: $\chi^2 = 9.76$, $p = 0.0018$), with no significant differences detected in Lábrea, Paragominas, or Tefé (*p*s > *0.19*). For example, urban respondents in São Félix were much more positive (agreeing or strongly agreeing with statements) than their rural counterparts about the importance of eating toasted manioc flour (57% urban versus 24% rural), bushmeat tasting nice (55% [urban] positive versus 29% [rural]), and forest extractivism being locally important (23% positive versus 6%)(Figure 4.5). Urban respondents expressed stronger forest identity values than their rural counterparts in early-frontier Lábrea ($\chi^2 = 9.60$, $p = 0.0019$) and intermediate-frontier São Félix do Xingu ($\chi^2 = 6.26$, $p = 0.0123$). For instance, people in Lábrea's urban centre expressed more very positive responses towards all four identity questions (mean 69% very positive responses ['completely agree']) relative to rural people in that municipality (mean 37% very positive responses). In rural São Félix rejection of forest identities included expressing negative or strongly negative opinions towards forests being

important (12% versus 5% in the urban area) or "part of who I am" (12% versus 3% in the urban area)(Supplementary Figure 4.4).

For the cattle identity and importance factor, we found no significant differences (at $p < 0.05$) between urban and rural respondents in any of the four municipalities, with only a weakly significant difference in early-frontier Lábrea ($\chi^2 = 3.17$, $p = 0.075$). Interestingly, the urban sub-population in Lábrea was very polarized in relation to the potential for social connections and collectivity on cattle-ranches, with 13% strongly agreeing and 6% strongly disagreeing. Cattle utility scores were significantly higher among urban respondents in Lábrea compared to their rural counterparts ($\chi^2 = 4.72$, $p = 0.0299$), with no other significant differences found across frontier stages. Nonetheless, perceptions towards pasture and cattle were highly polarized in all rural and urban sub-populations (Table 4.4). Overall, differences between urban and rural respondents in RVs were context specific, emerging only in certain frontier stages and RV types.

Table 4.3. Descriptive statistics (mean ± SE) of traditional Amazonian culture and cattle culture factor scores across rural and urban areas between frontier stages (with named municipalities for each frontier stage in brackets), and the number of interviews per rural/urban area in each frontier stage.

Rural/Urban, Frontier Stage	Forest Utility	Forest Identity & Importance	Cattle Utility	Cattle Identity & Importance	Number of interviews
Rural, Pre (Tefé)	0.20 ± 0.06	0.11 ± 0.08	-0.07 ± 0.07	-0.30 ± 0.07	43
Urban, Pre (Tefé)	0.12 ± 0.05	0.01 ± 0.06	-0.19 ± 0.05	-0.41 ± 0.05	69
Rural, Early (Lábrea)	0.38 ± 0.05	0.26 ± 0.08	-0.05 ± 0.05	-0.09 ± 0.04	41
Urban, Early (Lábrea)	0.45 ± 0.04	0.57 ± 0.05	0.12 ± 0.08	0.06 ± 0.07	67
Rural, Intermediate (São Félix do	-0.57 ± 0.05	-0.51 ± 0.10	0.26 ± 0.10	0.40 ± 0.09	34

Xingu)					
Urban, Intermediate (São Félix do Xingu)	-0.31 ± 0.05	-0.19 ± 0.06	0.11 ± 0.07	0.26 ± 0.06	57
Rural, Late (Paragominas)	-0.25 ± 0.06	-0.27 ± 0.08	-0.12 ± 0.10	0.09 ± 0.09	33
Urban, Late (Paragominas)	-0.27 ± 0.04	-0.30 ± 0.05	-0.06 ± 0.06	0.10 ± 0.05	60

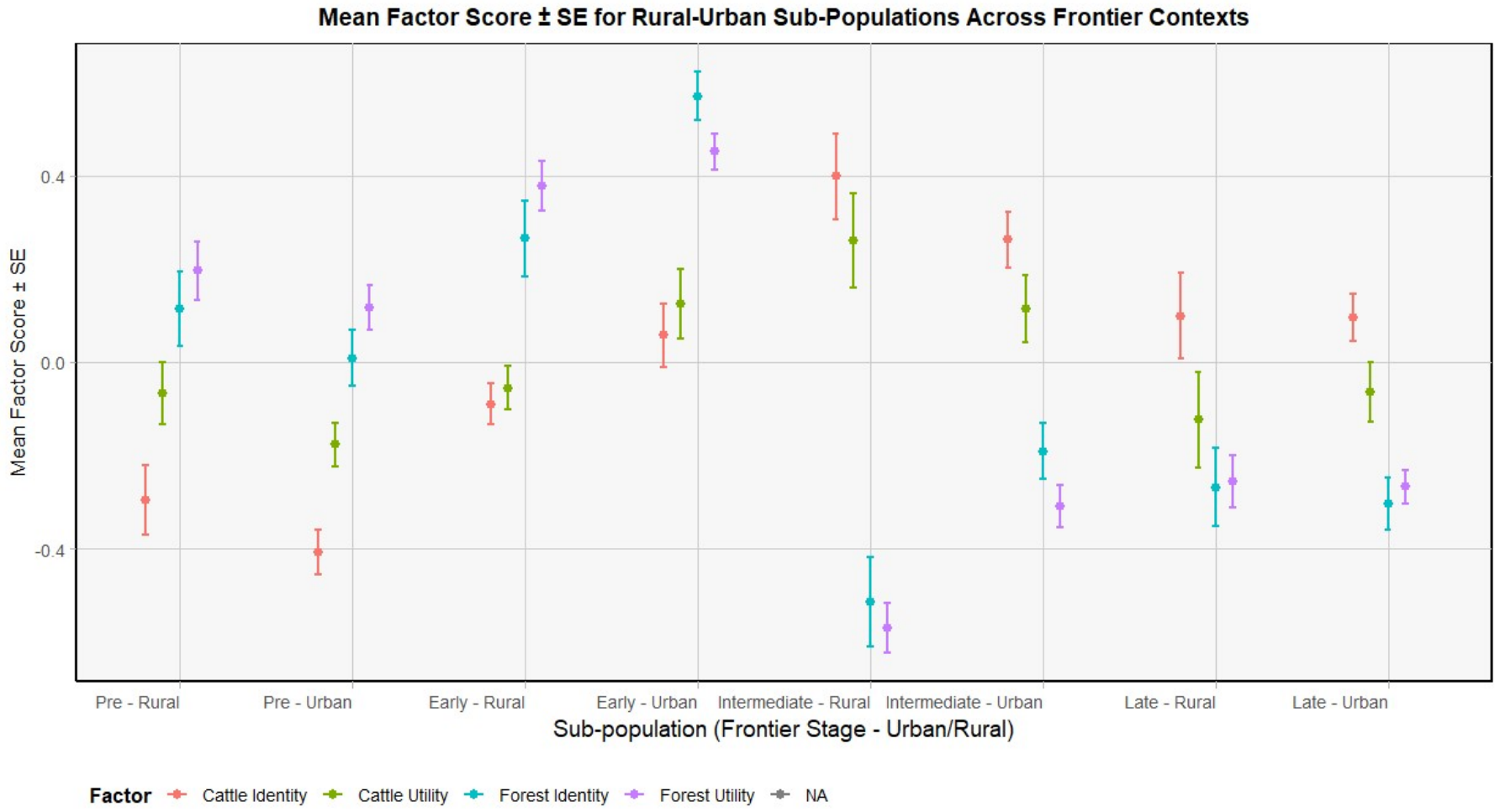


Figure 4.4. Mean factor scores for four kinds of relational values (Forest Utility, Forest Identity, Cattle Utility, Cattle Identity) across four deforestation frontier stages and urban/rural sub-populations in the Brazilian Amazon. *Points represent mean scores, and error bars indicate ± standard error. Sub-populations are ordered from early to late frontier stages and split by rural and urban respondents.*

There were significant interactions between frontier stage and urban/rural setting for multiple RV factors (Table 4.4). In rural areas, forest utility scores were significantly lower in intermediate and late frontier contexts compared to rural pre-frontier settings ($\beta = -0.73$ and -0.39, respectively; both $p < 0.001$), while early frontier rural scores did not differ significantly from pre-frontier rural scores. Similarly, in rural settings, forest Identity scores were significantly lower in intermediate and late frontier contexts ($\beta = -0.59$ and -0.31, $p < 0.001$ and $p < 0.01$, respectively) compared with pre-frontier rural locations. Cattle identity & importance and cattle utility factor scores in rural areas were significantly higher in intermediate frontier São Félix do Xingu respondents ($\beta = 0.72$ and 0.32, respectively; $p < 0.01$) and lower in pre-frontier Tefé respondents ($\beta = -0.30$, $p < 0.001$) relative to other rural sub-populations.

Urban-rural differences varied across frontier stages. In urban areas, forest identity scores were higher in early and intermediate frontier municipalities relative to pre-frontier urban locations ($\beta = 0.47$ and 0.41, respectively; $p < 0.01$). However, absolute mean factor scores indicate that intermediate frontier urban respondents had lower pro-forest values in absolute terms than pre-frontier urban respondents (mean forest utility = -0.31 vs. 0.12; mean forest identity = -0.19 vs. 0.01). The positive interaction coefficients for intermediate urban respondents reflect differences relative to the model's reference group (pre-frontier rural), rather than high absolute values. Similarly, urban intermediate respondents had slightly higher cattle utility and cattle identity scores than the model would predict from main effects, although absolute scores remained comparable to other sub-populations.

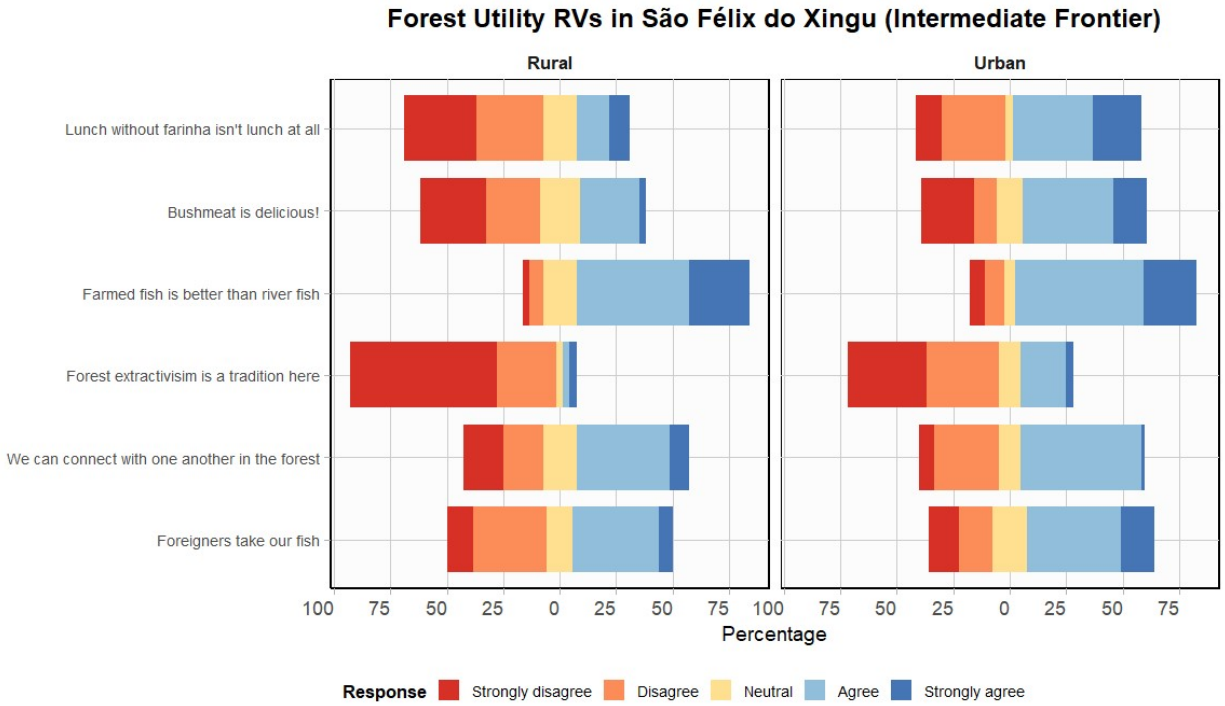
In summary, rural people in pre-frontier and early frontier locations held stronger pro-forest RVs compared to rural people in intermediate and late frontier locations, who reported lower absolute pro-forest scores. Rural respondents in early and intermediate frontier areas demonstrated higher pro-cattle RVs than rural respondents in pre- and late-stage frontier locations. Among urban populations, absolute pro-forest RVs were lower in intermediate frontier municipalities, despite positive interaction coefficients in the linear models relative to the pre-frontier rural reference group. Rural-urban differences in RVs were therefore frontier stage- and context-specific: Urban populations in early frontier Lábrea exhibited the highest pro-forest RVs, whereas rural

populations in intermediate frontier São Félix do Xingu exhibited the highest pro-cattle RVs.

Table 4.4. Robust Linear Model results comparing effects of rural and urban settlement across frontier stages on relational values factor. Entries are standardized coefficients (β) with robust standard errors in parentheses. Reference category is Pre-Frontier, Rural. Significance approximated using |t| > 1.96 thresholds. † = p < .10, * = p < .05, ** = p < .01, *** = p < .001.

Predictor	Forest Utility Factor β (SE)	Forest Identity Factor β (SE)	Cattle Utility Factor β (SE)	Cattle Identity & Importance Factor β (SE)
Intercept (Pre-Frontier × Rural)	0.16 (0.05)***	0.09 (0.07)	–0.07 (0.08)	–0.30 (0.07)***
Early Frontier x Rural	0.20 (0.07)**	0.14 (0.10)	0.01 (0.11)	0.22 (0.10)*
Intermediate Frontier x Rural	–0.73 (0.08)***	–0.59 (0.11)***	0.32 (0.11) **	0.72 (0.11)***
Late Frontier x Rural	–0.39 (0.08)***	–0.31 (0.11)**	–0.15 (0.11)	0.34 (0.11)**
Urban x Rural	–0.08 (0.07)	–0.12 (0.09)	–0.10 (0.1)	–0.12 (0.1)
Early × Urban	0.17 (0.09)	0.47 (0.13)***	0.29 (0.14)*	0.25 (0.13)*

Intermediate × Urban	0.32 (0.1)**	0.41 (0.14)**	–0.06 (0.14)	–0.05 (0.13)
Late × Urban	0.03 (0.1)	0.01 (0.14)	0.22 (0.14)	0.15 (0.13)



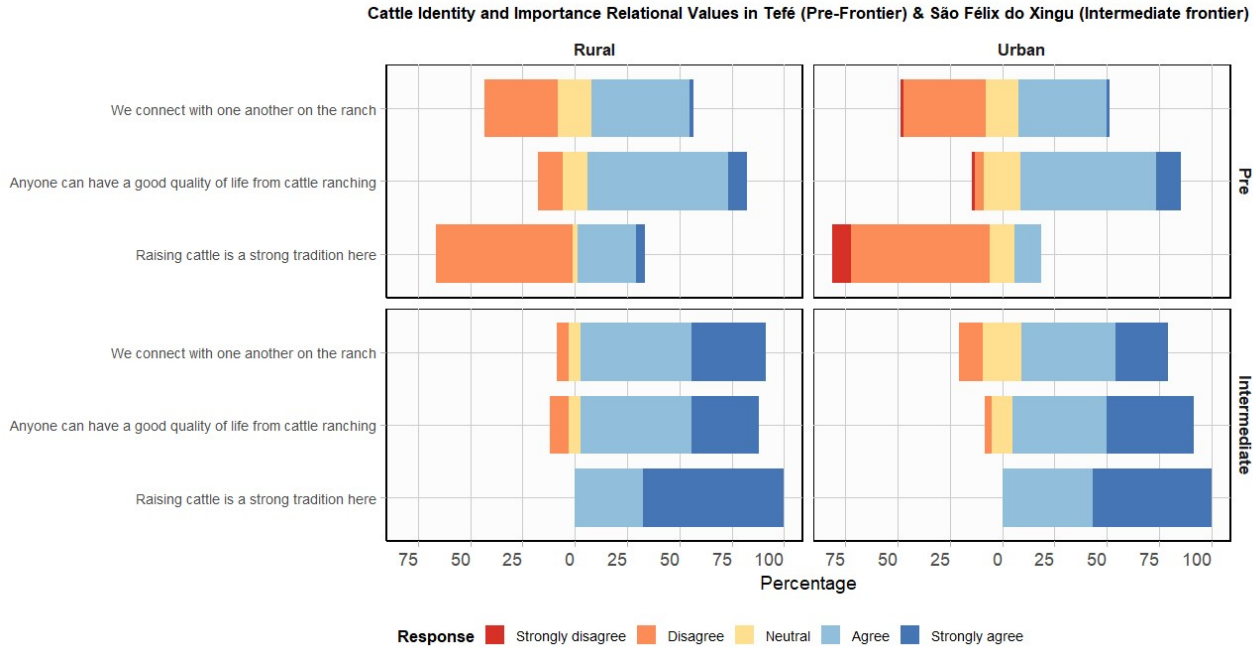


Figure 4.5. Pro-forest utility associated RVs questions and response frequencies in São Félix do Xingu (top) and pro-cattle identity and importance associated RVs questions and response frequencies in pre-frontier Tefé and São Félix do Xingu (bottom) from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages.

Q4.3) How are relational values of rural people related to the local environment and land-use?

Rural people living in more forest-dominated landscapes tended to have higher pro-forest RVs (Figure 4.6). Using log ratio predictors, higher forest coverage within 1km of rural households was associated with significantly higher forest utility factor scores (β = 0.097, $p < 0.001$, $R^2 = 0.30$)(Table 4.5). Similarly, forest identity and importance factor scores were significantly higher among people living in more forested landscapes (β = 0.074, $p < 0.001$, $R^2 = 0.12$). In summary, relative forest cover close to rural households was strongly associated with higher pro-forest RVs expressions among rural people.

In addition, rural people living in more pasture-dominated landscapes had higher pro-cattle RVs. This was highly significant for cattle identity and importance factor scores when there was a more pasture around households ($\beta = 0.055$, $p < 0.001$, $R^2 = 0.14$)(Table 4.6). People living within more pasture-dominated landscapes also tended to express significantly higher perceptions of cattle utility ($\beta = 0.026$, $p < 0.05$, $R^2 =$

0.03). Consequently, pasture dominance was associated with people holding stronger values towards the utility of cattle and its importance for their identities.

The positive association between relative forest cover and pro-forest values (Forest utility: $\beta = 0.097, p < 0.001$; Forest identity and importance: $\beta = 0.074, p < 0.001$) was robust to controlling for intra-municipality spatial autocorrelation (using cluster-robust standard errors (Table 4.5)). In addition, cattle identity and importance scores were still higher in more pasture-dominated landscapes ($\beta = 0.055, p = 0.011$) when applying this control, yet the effect became non-significant for the expression of cattle utility relational values ($\beta = 0.025, p = 0.156$).

Overall, the relational values of rural people were strongly aligned with local land-cover composition. People living in more forested landscapes exhibited stronger expression of forest utility and forest identity and importance values, while households surrounded by pasture showed stronger pro-cattle values.

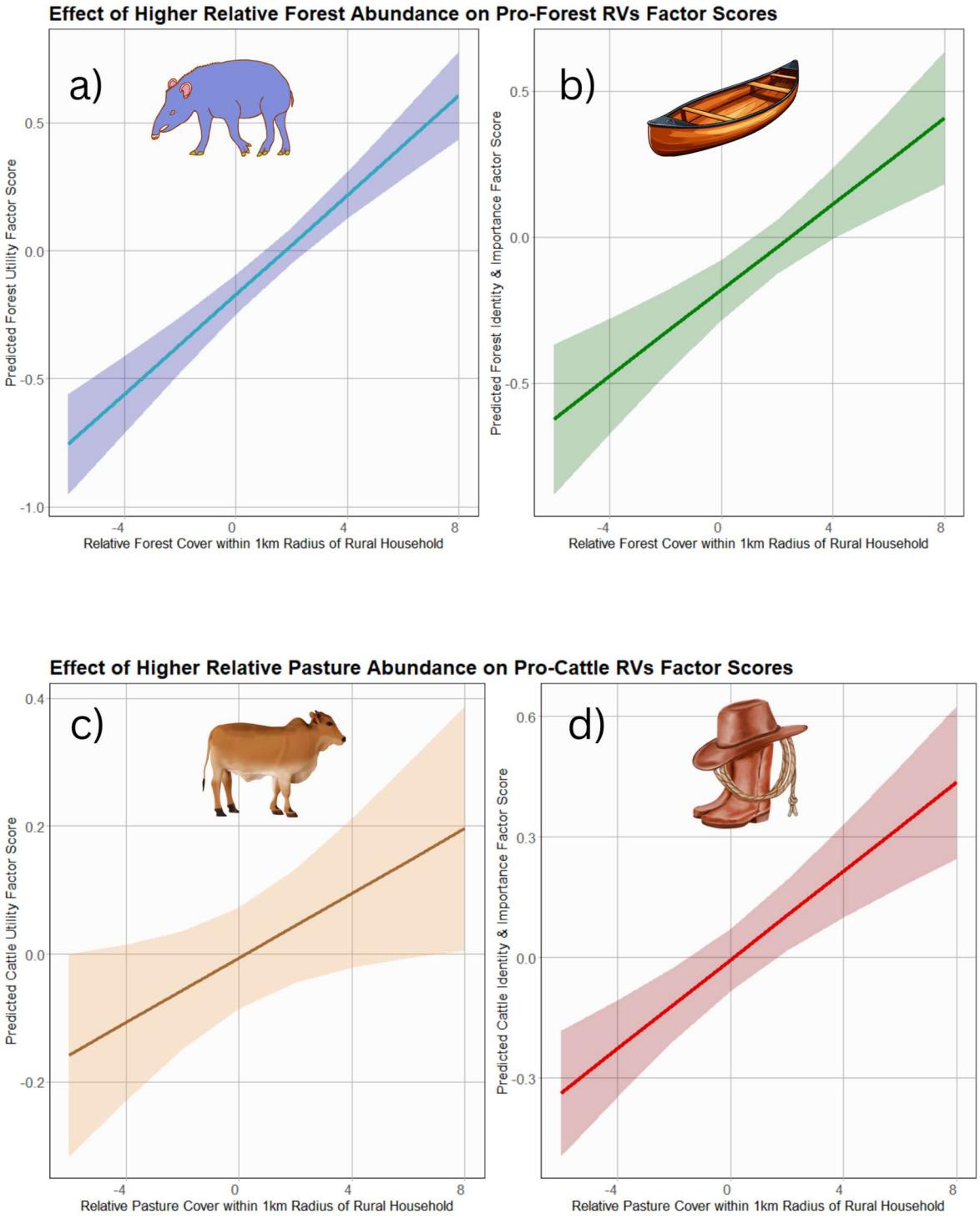


Figure 4.6. Modelled effects of higher relative land cover (log ratio of compositional land-use data) of forests and cattle pasture for four relational value factor scores:

a) Forest utility, b)forest identity and importance (Top); and c) cattle utility, and d) cattle identity and importance (Bottom). Shaded areas around the modelled curves represent the standard error of each effect. Forest cover captures forest cover relative to all other land-cover

types, and pasture cover relative to all other non-redundant land-cover types within a 1km radius (i.e. 3.14 square kilometres) of sampled rural households across all frontier stages (municipality).

Table 4.5. Summary of linear (LM) and Clustered standard error linear model results predicting pro-forest relational value (RV) factor scores: Forest utility, forest identity and importance. Each model includes one predictor variable: Log ratio of forest relative to other landcover types within 1km radial buffer of rural households. Standard errors for both models are reported, as are t statistic and p values for the clustered models to control for intra-municipality clustering using cluster-robust standard errors.

Response Variable	Predictor	Estimate	Std. Error (OLS)	Std. Error (Clustered)	t / p-value (Clustered)
Forest utility RV factor scores	Log ratio of forest relative to other land-cover types	0.097	0.0123	0.0213	4.579 / $p <$ *0.001*
Forest identity and importance RV factor scores	Log ratio of forest relative to other land-cover types	0.074	0.0162	0.0200	3.685 / $p <$ *0.001*

Table 4.6. Summary of linear (LM) and Clustered standard error linear model results predicting pro-cattle relational value (RV) factor scores: Cattle utility and Cattle Identity & Importance. Each model includes one predictor variable: Log ratio of pasture relative to other landcover types within 1km radial buffer of rural households. Standard errors for both models are reported, as are t statistic and p values for the clustered models to control for intra-municipality clustering using cluster-robust standard errors.

Response Variable	Predictor	Estimate	Std. Error (OLS)	Std. Error (Clustered)	t / p-value (Clustered)
Cattle utility RV factor scores	Log ratio of pasture relative to other land-cover types	0.055	0.0111	0.0215	2.577 / $p < 0.05$
Cattle identity and importance RV factor scores	Log ratio of pasture relative to other land-cover types	0.025	0.0112	0.0177	1.427 / $p = 0.156$

4.4 Discussion

Deforestation in the Brazilian Amazon has been widely studied through ecological and economic lenses yet understudied in relation to the social and cultural transformations which may accompany advancing agricultural frontiers. The role of human values, particularly of relational values – which connect identity, culture and environment – remains comparatively underexplored. Comparing four Amazonian municipalities in different stages of deforestation frontier advance, this study adopts a novel approach to examine how relational values can be formed, disturbed, and transformed in response to

social-ecological upheaval. Our findings demonstrate that relational values are neither static nor uniform, but respond dynamically to ecological change, social context, and local land-use.

Relational values attached to forests (trees, rivers, lakes) were strongest in populations in pre- and early frontier contexts, but these attachments weakened in later frontier stages, being replaced by values associated with cattle, the protagonist in most Amazonian deforestation (Pendrill *et al.*, 2022; Levy *et al.*, 2023). The composition of these relational values was highly context specific: urban people in the early frontier municipality of Lábrea demonstrated stronger pro-forest values than any other sub-population, while rural interviewees in the intermediate frontier of São Félix do Xingu, as expected, exhibited the highest pro-cattle values. Among the diverse rural actors sampled in this study, environmental relational values were generally closely aligned with the landscapes in which people lived, with pro-forest and pro-cattle expressions tracking the relative coverage of forests and pasture, respectively. Together, these results provide empirical evidence that the RVs of rural and urban Amazonians may transform as expansive forests become deforested and converted into pasture-dominated landscapes, at least unless meso-scale deforestation is halted by the creation of protected areas. In Brazil, sustainable development reserves and indigenous lands are effective in reducing deforestation (Silva-Junior *et al.*, 2023), and are mostly created through bottom-up community demands for territorial recognition (Parry *et al.*, 2025). This raises the intriguing possibility that although the spread of cattle culture appears intimately linked with frontier advance, successes in slowing this advance rely on *forest culture,* in terms of a common sense of desirable forest-centric livelihoods, landscapes and identities shared by insurgent forest citizens (Parry and Peres, 2015). Our results reinforce contemporary theoretical advancements that outline RVs as complex (Gould, Jimenez Naranjo and Balvanera, 2025), multi-faceted (Maller, 2021; Raymond *et al.*, 2023), and multi-directional (Hoelle, Gould and Tauro, 2022). Overall, this study advances understanding of how relational values respond to landscape simplification driven by agricultural expansion, using empirical evidence from one of the world's most important and contested deforestation frontiers, the Brazilian Amazon.

4.4.1 Relational values are linked to social-ecological context

We demonstrate that rural Amazonians RVs towards forests and cattle are strongly associated with the landscapes in which they live, work, and interact. The implication of this, based on our space-for-time substitution, is that when forested landscapes become transformed – including through the violent dispossession of traditional populations by armed gangs funded by powerful elites – into ecologically depleted pasture-dominated landscapes, people's sense of self and relationships with their surroundings tends to become more ambivalent towards forests and more inter-twined with cattle and alternative views of development. Yet it remains unclear if this is due only to migration and population turnover at frontiers, or because an individual's environmental values shift during the years of landscape transformation.

Considering the question of how relational values change across deforestation frontiers, we found that RVs associated with the importance of the forest to local identity and the utility of forest resource use were more pronounced in pre-frontier and early frontier settings. The particularly high pro-forest values in early frontier Lábrea (higher even than pre-frontier Tefé) may be explained by Lábrea's relative isolation on the River Purus (five days boat journey from the state capital, Manaus) and its smaller urban population, which contrasts with Tefé's more heterogeneous population composed of migrants from elsewhere in Brazil and Amazonia, partly due to large military bases and other government institutions (Parry *et al.*, 2018). Moreover, the urban centre of Lábrea -- and the rural areas we sampled – are on the Purus riverside and far from the main recent deforestation activity (see Supplementary Figure 3.1a and compare with our rural sample in Figure 3.1b), albeit there is deforestation and cattle-ranching along the Trans-Amazon highway, whose terminus is the urban centre. To reiterate, for logistical reasons our samples of rural actors were intended to capture 'typical' social groups in that municipality but are somewhat limited by the size and spatial distribution of each sample. Interestingly, relatively high pro-forest RVs in Lábrea co-occurred with a stronger expression of values of cattle-centric identities, and the perceived utility of owning cattle, compared to pre-frontier Tefé. This study-wide high in pro-forest values in Lábrea (despite the higher pro-cattle values than the early frontier) may indeed mirror the historical resistance that traditional communities in this municipality have put up against the violent displacement of communities and forest clearance for cattle pasture

(Aleixo and APADRIT, 2011). This suggests that relational values and relationships with landscapes and nature are sensitive to agricultural expansion, which is evidenced by both values being highly contested in the early frontier, while pro-forest values had effectively been substituted by pro-cattle values in the intermediate frontier. This may indicate a replacement or substitution dynamic between these values, rather than an erosion of values as a result of the simplification of abundant landscapes such as forests (Riechers *et al.*, 2020).

The pronounced pro-forest values in early frontier contexts highlight that RVs can peak during transitional stages, potentially as communities negotiate new livelihoods, land-use pressures, and social norms (Kendal and Raymond, 2019) or indeed work collectively for recognition in order to resist forces of change and dispossession. Violence and conflict has been studied extensively in political ecology yet – alongside power and politics more generally – is notable by its absence as a focus in relational values research. These patterns underscore that relational values are highly sensitive to both local environmental conditions and the social-ecological context of the agricultural frontier, demonstrating that they are dynamic and adaptive rather than fixed traits (Himes *et al.,* 2025). Interestingly, despite the spatial independence from cattle-pasture of the people that we surveyed in the early frontier municipality of Lábrea (cattle-pasture encroachment in the South and Northwest, and densely forested extractive reserves and protected areas present on the East and throughout) pro-cattle values were higher than among respondents in the early frontier of Tefé. This transitional pattern may be enabled by the coalescing frontier mixture of political, ecological, and land-use factors, showing how relational values and identities are shaped by the uneven and non-linear progression of frontiers (Thaler, 2017). As such, Lábrea's unique geographical context and strong grassroots resistance to forest encroachment in the 2000s (Aleixo and APADRIT, 2011) may mean that traditional forest communities (including now urban inhabitants) may maintain and even strengthen their pro-forest values partly through collective acts of resistance, but that some values can shift with the arrival of migrants who tend to hold less favourable views of forests and stronger relationships towards cattle and pasture. These findings may support qualitative interpretations of shifts towards small-scale cattle adoption and agricultural diversification among forest-dependent communities (Gomes, 2009; Gomes, Vadjunec & Perz, 2012), emphasizing that understanding relational values in Amazonia requires attention to local social-

ecological processes, political contexts, and the uneven progression of frontier dynamics.

An important finding was that pro-cattle associated RVs peaked in the intermediate frontier (São Félix), where ongoing deforestation is most active, coinciding with a marked reduction in pro-forest RV expressions. This pattern suggests that pro-forest and pro-cattle RVs can overlap temporarily during transitional stages, but eventually, pro-cattle values begin to replace forest-related values rather than coexist indefinitely. These findings are consistent with ethnographic accounts of the role of cattle in shaping both landscapes and cultural values (Hoelle, 2015, 2018), as well as geography literature that underlines the ecological marginalisation of forest-dependent people during agricultural frontier expansion (Levers *et al.*, 2021). Moreover, in the late-stage frontier municipality, Paragominas, we observed a notable decline in cattle-related RVs intensity, without a corresponding resurgence of pro-forest RVs. This is perhaps unsurprising given that deforestation, illegal logging and cattle-ranching in Paragominas surged from the 1970s through to early 2000s, after which began a transition to large-scale mechanized farming (mainly soy)(Viana *et al.,* 2016). This pattern may indicate a social-ecological tipping point, where the progression of frontier expansion and subsequent landscape simplification leads to a homogenization of relational values and identities, whether forest- or cattle-related, once frontier activity stabilizes (Fernández-Giménez *et al.*, 2017; Milkoreit *et al.*, 2018)This may be present through the collapse of relational values towards forested landscapes, where the ecological and material basis for forest-related RVs is weakened (Riechers *et al.*, 2020), e.g. after decades of intensive logging in Paragominas, the forests are largely devoid of valuable timber). Further, the comparatively higher landscape coverage of pasture – and not forests – may serve to narrow both experiences with nature and thus, the relational values that accompany them. Interestingly, this may confound previous findings that indicate nature connection and forest cover in Amazonia are secondary to social factors that shape how people interact with nature (Mikołajczak *et al.,* 2021). Importantly, this would suggest that interventions aiming to avoid the replacement of pro-forest values may be most effective before frontier landscapes become highly simplified, as cultural and ecological systems may become locked into alternative states once simplification reaches a critical threshold (Graham *et al.*, 2023).

4.4.2 Rurality and relational values

Our second research question aimed to understand whether rural and urban sub-populations have distinct relational values. Although we found no overall rural-urban differences in values, differences emerged for specific frontier stages. Indeed, rural respondents were the primary drivers of variation in RVs across the frontier gradient and increasing municipality-scale deforestation and larger cattle herds were associated with marked swings between pro-forest and pro-cattle orientations. This shift was especially pronounced among rural residents in the intermediate frontier of São Félix do Xingu, who demonstrated the most notable pro-cattle values while also having the weakest pro-forest values. In contrast, although highly diverse in each place, urban populations generally displayed more stability in their value orientations with frontier advance, with only minor variation in mean values across frontier stages. These results suggest that in regions undergoing rapid landscape transformation, rural populations — whose livelihoods and identities are closely tied to land use — show more pronounced shifts in RVs, while in urban contexts values toward forests and cattle remain more heterogeneous and contested. This supports existing studies linking rural forest-based livelihoods to environmental value change, indicating that disturbances to forested landscapes may weaken the values that rural people attribute to forests in post-frontier regions of Amazonia (Carignano Torres *et al.*, 2016). Moreover, these results may highlight that urban sub-populations can develop distinct relational values to their rural counterparts because of the distinct nature of urban and rural ecologies that provide different opportunities to experience nature (Ono, Boyd and Chan, 2023). Cities, as distinct social-ecological systems from rural parts of a municipality, generate relational values that are also shaped by migration, a heightened access to global culture than rural areas, and institutional presences, rather than direct interaction with landscapes that are being transformed (Bashan, Colléony and Shwartz, 2021). In Amazonia, urbanization often involves rural-urban migrants – for instance in a study of nearly 800 households in four Amazonian urban centres, 57% of households were headed by a rural-urban migrant (Carignano Torres, Morsello and Parry, 2022) – who maintain enduring connections to rural systems (Beza *et al.*, 2018; Rangel, do Nascimento and Ramos, 2024) including strong rural-urban mobilities and practices including forest-based livelihoods, and harvesting and consuming wildlife (Parry, Barlow and Pereira, 2014; Carignano Torres *et al.*, 2022), This may result in hybrid values that are fundamentally

different in their composition. These findings suggest that in frontier contexts, changing rural populations (perhaps in the sense of either population turnover or when some smallholders switch from forest-based livelihoods towards cattle-raising) lead the transformation of relational values in frontier regions undergoing significant and rapid ecological change, whereas urban populations maintain distinct and diverse relational values towards landscapes than their rural counterparts.

4.4.3 Local land-cover and relational values

A major finding was evidence of strong linkages between nearby landscape composition and the RVs held by rural Amazonians. As expected, we found that living in and around forests was associated with stronger expressions of pro-forest values, while more extensive pasture-dominated landscapes were associated with stronger pro-cattle values. These findings are consistent with existing literature demonstrating that proximity and access to nature foster stronger connections to the environment, which in turn manifest in pro-environmental beliefs and behaviours (Beery and Wolf-Watz, 2014; Kleespies and Dierkes, 2020; Teixeira *et al.*, 2023; Lengieza and Aviste, 2025). Interestingly, these findings may contradict previous research that found the link between nature connection and forest cover in Amazonia to be secondary to social factors (Mikołajczak *et al.,* 2021). Our results align with work in post-frontier regions of the Brazilian Amazon that found people to be living in more forested landscapes to express higher non-material values for forests (Carignano Torres *et al.*, 2016), including those conceptualised as ‘identity’ or ‘meaningful and reciprocal relationships with nature’ in the RVs literature (sense Himes *et al.,* 2024). Importantly, this pasture~values result is congruent with suggestions from ethnographic research that strong RVs can be formed for cattle and pasture in rural frontier contexts undergoing rapid landscape transformation (Hoelle, Gould and Tauro, 2022). This highlights that RVs are not restricted to forests or ‘desirable’ biodiversity but can equally attach to landscapes and species commonly understood to be unsustainable and directly at odds with global climate goals, given that cattle ranching remains the leading driver of land-use and land cover change in Amazonia (Garrett *et al.*, 2018, 2024). Importantly, these pro-cattle values are actively reinforced by state policies, infrastructure investments, and market incentives that make cattle ranching one of the most viable livelihood strategies at the frontier (Skidmore *et*

al., 2021). Our results suggest that in these settings, cattle and pasture become deeply entangled with identity, livelihood security, and social status (Hoelle, 2015), illustrating how frontier dynamics may simultaneously alter the composition of RVs while exacerbating global environmental and local ecological crises. Taken together, these insights complicate a prevailing tendency in the RVs literature to date that equate RVs to pro-environmental outcomes, showing instead that RVs can be equally powerful factors in environmentally destructive practices when linked to certain landscapes and species (Hoelle, Gould and Tauro, 2022).

4.4.4 Policy implications

Forest conservation policies and interventions in the tropics must be informed by local values considerations (Barlow *et al.,* 2018), which will be underpinned by our understanding of a broad diversity of relationships with nature (Tengö *et al.*, 2017; Reed *et al.*, 2019; Carmenta, Zaehringer, *et al.*, 2023). In this paper, we have demonstrated how RVs can change in tandem with growing environmental pressures albeit we cannot ascertain the causality of this relationship using our empirical findings. It is plausible that ongoing and historic deforestation can erode the RVs associated with forests among the rural people who stay (Riechers *et al.*, 2020) - if they can avoid violent dispossession. Pro-cattle RVs may develop through daily experiences of and proximity to deforested landscapes through everyday practices (Hoelle, 2018; Hoelle, Gould and Tauro, 2022). Importantly, RVs are considered to be strongly related to pro-environmental attitudes and beliefs (Zafra-Calvo *et al.*, 2020), but our results also suggest that RVs can form around unsustainable land uses, such as cattle pasture. This implies that policies designed to transform landscapes are not neutral with respect to values. Instead, they may find support or opposition depending on the diverse and deeply held RVs present in a community or region. In other words, landscape change may be accompanied by a relatively benign or indeed a violent, contested (in a social and political sense, when considering frontier violence) process of value change, reinforcing the need for conservation and development initiatives to consider the complex social-ecological dynamics that shape local value systems.

Targeted conservation policies should not only be ambitious, but also culturally appropriate, considering the diversity of worldviews, beliefs and lived experiences in

the regions they target (Garrett *et al.*, 2024; Koehrsen and Ives, 2025). They should also realistically account for existing value systems and cultural norms (Manfredo *et al.*, 2021). In other words, conservation interventions should be grounded in the specific social and ecological contexts in which they are implemented (Carmenta, Barlow, *et al.*, 2023). Central to the potential for sustainability transformations through RVs is the emphasis on centring traditional values systems and relational connections with nature, often drawing on Indigenous ways of knowing and being that predate capitalism and colonialism (Nugent, 2009; Gould, Martinez and Hoelting, 2023; West *et al.*, 2024; Virtanen *et al.*, 2025). Notably, our empirical study did not survey the values of indigenous peoples and instead the traditional forest-dependent communities we sampled in Tefé and Lábrea are themselves the descendants of rubber-tapper migrants from Northeast Brazil, Europeans, and Amerindians. Nonetheless, our findings highlight that RVs can also emerge around landscapes that are directly at odds with traditional or sustainable management, such as cattle ranching in frontier Amazonia (Hoelle, Gould and Tauro, 2022). This raises important questions of political ecology, namely whose voices and values are represented in decision-making, and whether local forest conservation policy interventions adequately reflect the diverse and sometimes conflicting nature of RVs in local communities. Although these insights can inform broader multi-national or high-level forest conservation strategies, we assert that the primary contribution lies in demonstrating that landscape change is inseparable from value change at the local scale, rooting our findings in an empirical exploration of RVs with respect to frontier context, rural-urban settlement status, and local land-use strategies of rural people. By foregrounding the local social-ecological context and examining RVs *in situ*, we bring attention to the social, and ecological dynamics that shape value formation at the community level, a perspective rooted in political ecology and conceptually heterodox ecological economics (as opposed to environmental economics and its assumptions of self-maximizing rational economic actors). If these complexities are overlooked, achieving durable shifts in values that support sustainable decision-making, and pro-environmental outcomes will remain extremely challenging indeed (Ives and Fischer, 2017).

4.4.5 Study Limitations

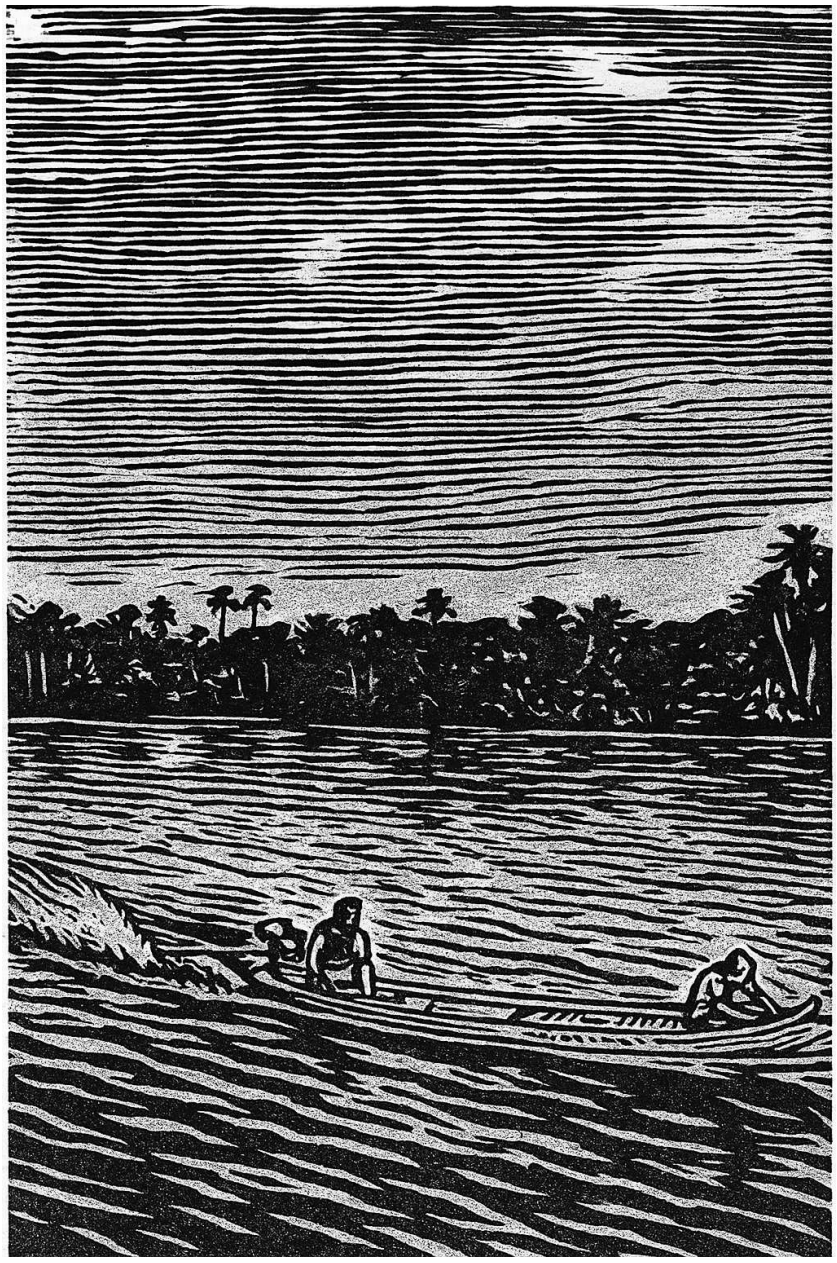
Although the study was designed with care, some key limitations should be addressed. One methodological limitation of this study is the design of the survey tool, which looked to capture a broad range of RVs for both forest and pasture. There are a dearth of studies that examine RVs empirically (Kleespies *et al.*, 2020). Studies that examine RVs in the chosen study context are few still, and ones that examine RVs for unsustainable land-use practices empirically through survey methods have not yet been published, to our knowledge. As such, the survey tool, while grounded in the latest conceptualisation of RVs at time of construction in 2024 (Himes *et al.,* 2024) and validated prior to data collection, was constructed from previous surveys measuring adjacent themes (Hoelle, 2015, 2018; Carignano Torres *et al.,* 2022; Mikołajczak *et al.,* 2021, 2023; and others) that do not explicitly measure relational values. This was perhaps most problematic during the survey validation stage, where some of the survey items had low factor loadings in final CFA analysis. Although this is to be partly to be expected in crafting new survey tools, this meant a reduction in the number of survey items that were included in final analysis. Secondly, study municipalities were selected in part due to existing community networks of co-investigators in the project team (LP, VG). Although this allowed for more fluid research activities in the field, this perhaps limited the types of land uses that this study would examine, and thus the breadth of RVs being captured by survey responses. Finally, while every effort to ensure a representative sample was obtained for urban respondents, the constitution of rural surveys was dictated by a mixture of contact with relevant community leaders, prior informed consent from community representatives, ethical approval of lead and co-authors to visit particular reserve types in highly forested regions, and time and transport constraints of PI (JOL) during the field season. Furthermore, rural communities across our sample vary significantly in size and geographic context, meaning a somewhat uneven spread in sample size per community, despite efforts to sample as evenly as possible.

4.5 Conclusions

Our results align with arguments that shifts in values can arise through social-ecological transformations, where large-scale ecological changes such as advancing agricultural

frontiers in the forested tropics alter the contextual values that people hold towards landscapes (Kendal and Raymond, 2019). Our novel empirical findings underscore the multifaceted nature of RVs and the possibility for strong values to emerge even for landscapes which are, ecologically-speaking, somewhat disastrous (Hoelle, Gould and Tauro, 2022). Rather than simply being eroded – and not replaced – in fragmented deforested landscapes, relational values may transform to reflect the landscapes people inhabit and reply upon (Riechers *et al.,* 2020). In frontier municipalities such as Lábrea, the emergence of pro-cattle values does not immediately displace pro-forest values, reflecting a longer history of cultural resistance by traditional communities to forest clearance and displacement in the region. Instead, both sets of values are actively negotiated in response to shifting environmental conditions and political-economic trajectories. Large-scale social transformations have long been observed in Amazonia, a region persistently re-shaped by capital through the hands of state and market interventions visions of the future, against a backdrop of grassroots resistance by local communities and indigenous peoples (Hecht and Cockburn, 1989; Hecht *et al.,* 2024). Importantly, our findings suggest that RVs are contingent not only on local land-use change but also on broader environmental changes that are dictated by political-economic forces, helping to explain why many of the strongest agreements with pro-forest or pro-cattle RVs were expressed by rural participants embedded in these transitions. Consistent with the wider RVs literature, we assert that the maintenance and fostering of pro-environmental values is achievable (Chan *et al.*, 2020; Horcea-Milcu *et al.*, 2023). Yet our study also supports emerging evidence that meaningful values – however problematic from an environmentalist perspective – can be formed around cattle and pasture, particularly with these practices enhance material security and social identity (Hoelle, 2018; Hoelle et al. 2022; Mikołajczak et al. 2023; Costa et al. 2024). A key contribution of our work is to conceptualise relational values as a process. Rather than static explanatory factors, they are constantly in flux, evolving with landscapes, and shaped by multiple interacting processes over time (Chan *et al.*, 2025; Merçon, 2025)Recognizing this dynamism is essential for policy-making. Tropical forest conservation and sustainability initiatives must account for the reality that RVs are not inherently just pro-forest, but are instead negotiated within frontier dynamics where livelihoods, identities, and power converge.

Chapter 5: Concluding Remarks



"Os rios, esses seres que sempre habitaram os mundos em diferentes formas,

The rivers, these beings that have always inhabited the world in different forms,

são quem me sugerem que, se há futuro a ser cogitado,

are the ones who suggested to me that, if there is a future to be considered,

esse futuro é ancestral, porque já estava aqui.

that future is ancestral, because it was already here."

(Ailton Krenak, Futuro Ancestral [Ancestral Future], 2022)

5.1 Key findings

With COP 30 looming in Belém at the time of writing the cultural capital of Amazônia, the Brazilian government's commitment to slowing agricultural-led deforestation is under renewed scrutiny (Fearnside and Filho, 2025). Despite decades of rigorous analysis from economic, political, and ecological perspectives, modelling of tropical deforestation drivers at various spatial scales has largely failed to integrate a critical component - *culture*. This thesis has demonstrated that people living in landscapes at different points along the deforestation continuum hold complex and distinct meaningful relationships with one another and their environment. It has also shown that cultural expression is deeply intertwined with dominant land-use strategies and modes of production across Amazônia, and that advancing deforestation frontiers profoundly reshape the relationships and values people develop with forests, including why they may, or may not, wish to protect them.

The first key finding of this research is that cattle ranching is deeply entangled with culture in complex ways: it is both a driver of landscape transformation and this environmental change then contributes to shaping cultural identities, values and behavioural expressions (see **Chapters 2**, **3** and **4**). Deforestation and opening pasture for cattle is also likely to *reflect* the changing identities and values of people living in human-dominated Amazonian landscapes (i.e. these human-environment relationships are bi-directional). At least based on our cross-sectional research in which we used spatial variation as an analogue for temporal change as frontiers advance, ranching appears to displace and erode the cultural norms tied to traditional ways of living with and in forested landscapes. In this sense, our results reinforce the notion that traditional peasant communities remain under threat, as victims of both social and ecological marginalisation (Levers *et al.*, 2021). These dynamics stem from a matrix of aggressive and often violent land-displacement tactics from more powerful actors (Hecht *et al.*, 2024; Thaler, 2024), coupled with ongoing struggles for constitutional and social *visibility* in Brazil's economic and political hierarchy (Nugent, 1993; Schmink, 2003; Fraser, 2018; Parry *et al.*, 2025). These contestations – including violence – are certainly notable in the environmental histories of the four municipalities where fieldwork was conducted (see *Section 3.2.1.1* of this thesis, and Figure 3.3). The expansion of cattle-driven deforestation frontiers therefore threatens not only

livelihoods, but the diverse forms of cultural expression, values and cosmologies that have been co-developed with the rainforest (Nugent, 1997; Vadjunec, Schmink and Greiner, 2012).

The second key finding of this research is that relational values for nature are multifaceted and emerge even toward pasture-dominated landscapes that are, ecologically-speaking, disastrous (see **Chapter 4**). When tied to enhanced material security and social identity, such landscapes can nonetheless acquire cultural salience and meaning to local populations (Hoelle, 2018; Hoelle, Gould and Tauro, 2022; Mikołajczak *et al.*, 2023). There is a rapidly growing conceptual basis for the values literature that relies on diverse and often Indigenous worldviews and cosmologies around nature (Tengö *et al.*, 2017; Anderson *et al.*, 2022; Raymond *et al.*, 2023; Gould, Jimenez Naranjo and Balvanera, 2025; Himes *et al.*, 2025). This literature has not yet adequately grappled with the positive, reciprocal relationships that rural people hold for landscapes and practices that are inconsistent with these cosmologies yet continue to shape much (un)sustainable development in the Global South (Hoelle, Gould and Tauro, 2022). Recognising the full diversity of these relationships is essential for developing more realistic understandings of how people value, use, and transform their environments accordingly, and thus, for designing an inclusive conservation science that resonates with lived cultural practices rather than idealised visions of sustainability (Maller, 2021; Carmenta, Barlow, *et al.*, 2023; Chan *et al.*, 2025).

5.2 The complex relationship between forest loss, cattle, and culture

This thesis helps to elucidate the complex relationship between forest loss, cattle herding, and culture across farm-forest frontiers of the Brazilian Amazon. In doing so, this research advances research into *nature~culture* interactions at farm-forest frontiers, beyond existing work at relatively small spatial scales (see Salisbury and Schmink, 2007; Hoelle, 2011, 2014, 2015; Kohler *et al.*, 2011; Zycherman, 2016, for examples). To the author's knowledge, only a handful of studies have interrogated this link empirically (see Gomes, Vadjunec and Perz, 2012; Hoelle, 2018). Subsequently, this thesis aimed to answer numerous questions about these relationships: (1) *How do musical preferences and other forms of cultural expression change across deforestation*

frontiers? (**Chapters 2, 3**); (2) *Do variations in cultural expression and environmental relational values across a deforestation gradient differ between urban and rural populations?* (**Chapters 3, 4**); and (3) *How are environmental relational values associated with deforestation and landscape change?* (**Chapter 4**).

Traditional Amazonian identities – which can be broadly associated with peasant societies, especially those living near forests and rivers -- have long been entrenched in forest-dependency and sustainable resource use (at least when fostered by the institutional environment). This thesis provides evidence that the associated cultural expressions, norms and values that are inherent to these traditional identities face tangible threats of displacement by identities centred around cattle raising in advanced agricultural frontiers. Cultural expression indicative of cattle culture and relational values towards pasture and cattle may become dominant in frontiers where rural land-use is primarily shaped by cattle ranching. Favourable cultural opinions associated with cattle and the increased material security, social status and symbolic aspects of *progress* for peasant and smallholders across Amazonia are hardly new (Siegmund-Schultze *et al.*, 2007; Hoelle, 2011). Yet, ethnographic research has indicated that cultural values associated with cattle in Western Amazonia can also be associated with unfavourable views about forests (Hoelle, 2015, 2018). The results of this research, taken with previous local-scale research, suggest that composition of people's relationships with one another and importantly, their environment, is distinct in different frontier contexts.

The findings of this thesis resonate with the idea that human-nature relationships are complex, consistently transforming and adjusting to both 'inner' (e.g. psychological, cultural domains, including identities, values) (Kempton and Holland, 2003; Ives, Freeth and Fischer, 2020) and 'outer' (e.g. economic, technological or ecological) phenomena (Riechers *et al.*, 2020; Mikołajczak *et al.*, 2023). Albeit this thesis has not examined such transformations over the life course of an individual person but instead assessed population-level changes in the average or dominant forms of cultural expression and relational values. Nonetheless, these inner and outer 'worlds' converge to influence the formation of unique, place-based identities (Cresswell, 2015), cultures, and values (Ives and Kendal, 2013; Whitehead *et al.*, 2014). The formation of these cultural identities in Amazonia is complex and entangled in the roots of colonial expansion (Cleary, 2001; Jacob *et al.*, 2021), diverse livelihood strategies that have stemmed from forest-dependency (Nugent, 1993; Heckenberger *et al.*, 2007; Steward,

2007), and violent agricultural frontier expansion over recent decades (Hecht and Cockburn, 1989; Wood and Schmink, 1993; Little, 2001; Thaler, 2024). Specifically, the agricultural sectoral focus on cattle as principal driver of LULCC in most parts of Amazonia continues to play a prominent role in reshaping these cultural identities and values of Amazonians in unprecedented ways (Hoelle, 2018; Hoelle, Gould and Tauro, 2022). This study demonstrates that this indeed true across multiple frontier contexts, adding to previous, local-scale inspections of the effect of cattle on Amazonian identities. Note, however, that in pre-frontier locations such as Tefé, the main driver of land-use change and deforestation continues to be traditional farm-fallow agriculture, mainly to open up fresh swidden plots for manioc.

In response to RQ5 of this thesis (*Can people's meaningful relationships with one another and their environments be quantified?*); my results suggest that people's meaningful relationships with one another and their environment can be effectively quantified, in the sense of showing conceptual and internal statistical validity. Moreover, I believe I have demonstrated that there is value in doing so, in order to better understand trends in changing cultural expression and relational values and environmental outcomes over large spatial scales. Global efforts to conserve tropical rainforests currently focus on various ecological, economic, political and social aspects of deforestation. A central dimension of the social, *culture,* has long been recognised as an important shaper of land-use decision making (Lambin, Geist and Lepers, 2003). However, it is yet to be properly integrated into statistical modelling approaches to explain and combat destructive LULCC (Caldas *et al.*, 2015; le Polain de Waroux *et al.*, 2021; Hodel, le Polain de Waroux and Garrett, 2024). This is perhaps a key reason that lasting, effective, and realistic sustainable management incentives in tropical forests, which have typically focused on financial remuneration for maintaining key ecosystem services (Arriagada *et al.*, 2018; Kolinjivadi, Van Hecken and Merlet, 2023), have often fallen short of lofty global climate agreements and goals (Scales, 2012; Carmenta *et al.*, 2020). In many cases, culture is crucial in forming and shaping the attitudes, views, and beliefs that people hold towards particular landscapes (Hoelle, 2018; le Polain de Waroux *et al.*, 2021). The novel methodologies developed in this thesis, such as the comparison of music with large-scale LULCC data, could help to elucidate patterns of cultural and environmental change in future, something which has been absent from the literature to date.

5.2.1 How do forms of cultural expression change across deforestation frontiers?

The results of **Chapters 2** and **3** of this thesis demonstrate that forest loss occurs in tandem with cultural change across the Brazilian Amazon, especially when this forest is replaced by pasture for cattle raising. Although central cultural aspects of cattle culture, like Sertanejo country music (Hoelle, 2015), have become relatively ubiquitous across Amazonia, my results show that this music is more dominant in areas with more cumulative deforestation and more cattle. Importantly, however, other forms of diversity in cultural expression that are associated with traditional peasant communities (such as eastern-Amazonian music and food preferences) are far less widespread according to my field data, suggesting that they have become squeezed out in these locations. Has Sertanejo music and other expressions of cattle culture essentially occupied and homogenise this cultural space? The results of this research suggest that largescale biocultural simplification may occur with the onset of cattle-driven deforestation frontiers (Hanaček and Rodríguez-Labajos, 2018).

Based on research presented in this thesis, I suggest that research into tropical deforestation may benefit from engaging with the concept (a novel one, I would argue) of agri-*cultural* frontiers, as a way of understanding the cultural dimension of frontier advance. Place-based identities and cultural values that have historically developed in pasture-dominated landscapes across south and south-eastern Brazil now feature as the prevalent social norms in the largely deforested, Amazonian municipalities studied by (Hoelle, 2014) and my own work in intermediate frontier stage, São Félix do Xingu. These shared cultural norms, practices, beliefs, and behaviours are external, and perhaps invasive, to the diverse Amazonian identities that have sustainably co-developed the immense biocultural diversity of the Brazilian Amazon to date (Hecht and Cockburn, 1989; Nugent, 1997; Heckenberger *et al.*, 2007). This represents not only a loss of ecological diversity, but also one of biocultural diversity, which opens up other moral and ethical critiques, beyond those relevant solely to the loss of primary forest (Nugent, 1993; Schmink, 2003; Fraser, 2018; Parry *et al.*, 2025).

5.2.2 How are relational values associated with deforestation and landscape change?

The results of **Chapter 4** of this thesis demonstrated that at the population level, people in Amazonia express a rich array of relational values; both for forest and pasture landscapes. This is important to acknowledge to help the conservation science community move past value monism (e.g. scientific value, monetary value of nature alone)(Merçon, 2025), and to consider the more complex and plural suite of values relevant to each context in which they arise (Himes *et al.*, 2025). This chapter highlights that relational values can be formed towards landscapes that are considered ecologically unsustainable (i.e. pastures are terrible from an ecological perspective, and cattle herd growth on a given farming property inevitably requires more pasture to support grazing requirements), supporting previous literature theorizing this to be the case (Hoelle, Gould and Tauro, 2022). Relational values have been theorised to be a transformative tool for achieving sustainability (West *et al.*, 2020; Gould, Jimenez Naranjo and Balvanera, 2025), which can complement utilitarian (Costanza *et al.*, 2017) or intrinsic (Preston, 1998) approaches to sustainability and nature conservation (Kleespies and Dierkes, 2020). This research extends the study of relational values, testing how a breadth of relational values manifest toward different environments in Global South contexts, including those which are not sympathetic to conservation (Hoelle, Gould and Tauro, 2022). The importance of recognising this diversity of relational values towards different landscapes (including those which are ecologically harmful) is a critical takeaway from this thesis.

Enhanced understanding and recognition of relational values towards pasture and cattle, and the potential consequences this holds for tropical forest conservation, are of paramount importance. This research achieves this not only by emphasising the breadth of relational values for varied landscapes, but by measuring these values across vast area and systematically exploring how they vary across the frontier. This represents a new dimension of the relational values literature, to my knowledge. The findings of this research also complement local-scale empirical work conducted by Jeff Hoelle (2018) in Acre (Western Amazonia), that evidenced how actors whose daily working practices involve cattle hold less favourable opinions about forests and the people that traditionally rely on them. The systematic cross-frontier design extends the takeaways

of this prior research, highlighting that similar cultural beliefs about forests could be pervasive across Amazonia an increasing number of people develop relational values for pasture and cattle in advancing agricultural frontiers. An important next step of this research would be to understand exactly how this translates to decision-making across frontier contexts, something that was beyond the scope of the current research project.

5.3 To what extent is cultural change at frontiers associated with migration?

In answering research question 3.4 of this thesis (**Chapter 3**) I have shown that people born outside of the Amazon hold distinct cultural markers than people born in Amazonia. Social change, such as changing values, can be as a result of the in-migration of new people to a social-ecological context (Kendal and Raymond, 2019). The diffusion of cattle culture, a central focus of this thesis, is said to occur as a result of both landscape conversion from forest to pasture and to the in-migration of people from outside of the Amazon, who hold distinct cultural values and norms, that are anchored in developmentalist worldviews, owing to the largely European ancestry of in-migrants (Hoelle, 2011, 2014, 2015). My results indicate that migration plays a role in the dominance of cattle culture in advanced deforestation frontier contexts, suggesting that in-migration from people born outside of the biome converges with local landscape change and developmental narratives to also influence cultural expression of locally born Amazonian people. However, the extent to which migrants themselves are the cause of this cultural domination, and potential shifting cultural identities of Amazonians was not independently explored in this thesis and therefore cannot be reasonably answered with my results. In order to answer these questions further, more dedicated study on the underlying mechanisms of cultural change in frontier areas, such as the power dynamics between people born outside of the Amazon and Amazonians (Robbins, 2019), and how this shapes migrant acculturation and adaptation in Amazonian landscapes (Berry, 1992).

5.4 Future directions

5.4.1 Empirical study of culture at large spatial scales

A central contribution of this thesis has been to implement innovations in measuring cultural expression using quantitative data (Pichl *et al.*, 2017; Stewart *et al.*, 2019; Way *et al.*, 2019; Vieira *et al.*, 2020) to local-scale studies of the link between environmental change and culture at farm-forest frontiers. Future research might make use of advancements in artificial intelligence to replicate statistical modelling of music data demonstrated in **Chapter 2**, albeit applied to other aspects of cultural expression. Music represented a relatively low-hanging cultural 'fruit', because of the importance of Sertanejo to cattle culture (Hoelle, 2015; Lima, 2019; Morais, 2020) and musical listening habits as everyday expressions of culture and identity (Tillman, 1980; Moore, 2004; Thomas, 2017). Yet, the method developed in this chapter, as well as subsequent chapters could be applied to other domains of cultural expression, such as food or clothing preferences, two aspects that were only touched upon in surveys (**Chapters 3** and **4**). Moreover, following Gomes *et al.'s* (2012) survey and statistical modelling of identity classifications among traditional Amazonian communities, and Hoelle's (2018) work to quantify cultural values associated with deforestation at a local scale in Acre, future studies could interrogate the links these authors had examined at larger spatial scales, taking inspiration from this thesis' methodological approach to do so.

5.4.2 Relational values in Global South contexts

A critical contribution of **Chapter 4** has been to extend the study of relational values into Global South contexts, where previous research had suggested that relationships between people and nature (such as nature connection) were seemingly not shaped by access to nature or forests, but rather by social factors (Mikołajczak *et al.*, 2021, 2023). Interestingly, previous research had shown conflicting answers, suggesting that deforestation and loss of contact with forests are related to the erosion of the emotive importance of nature to people across Amazonia (Carignano Torres *et al.*, 2016), a result that is congruent with the findings of this research. Future research could aid to anchor relational values more concretely in the diverse knowledge systems and contemporary

relationships that people hold with each other and nature in the Global South. It is critical that this literature properly represents the wide array of diverse values of forest-proximate people worldwide, millions of which in the Brazilian Amazon are traditional peasant communities (Parry *et al.*, 2025). Being more attuned to these knowledge systems, which have laid the foundations for many successful forest reserves across the Amazon (Hecht *et al.*, 2024), should therefore be a key future research priority.

Furthermore, relational values have typically been studied in singular places, and still utilise relatively abstract notions of value, or draw on Indigenous cosmologies (Gould, Martinez and Hoelting, 2023; Himes *et al.*, 2025) that are inconsistent with many developmentalist worldviews that govern much forest resource management in Brazil and more broadly, the tropics. While this thesis has built on previously slim examples of quantifying relational values to this point (Kleespies and Dierkes, 2020; Uehara, Sakurai and Tsuge, 2020), the literature still lacks empirical weight, which will only be achieved through repeated empirical studies across variform contexts where other ecologically and culturally important landscapes that are under threat and are different from those examined in this thesis, of which there are undoubtedly many.

5.4.3 The role of religion in shaping environmental values and cultural expression

An area of great intrigue that this thesis did not cover in any significant depth is the role of religious cultural expression and religion more broadly in shaping cultural expression and environmental values across Amazonia. **Chapter 2** demonstrated the widespread cultural significance of Gospel music across the biome, which was the second most popular genre of music behind only Sertanejo. Importantly, Gospel music had an even stronger negative effect on musical diversity of radio stations than Sertanejo on average in this chapter. Anecdotal evidence from fieldwork suggests that this is because for many Evangelical Amazonians, Gospel is the only music that they frequently listen to (confirmed on rural fieldwork in 2024; Supplementary Table 2.3).

This avenue of research could prove to be especially interesting because of recent work that highlights the role of religion in shaping pro- and anti-environmental values, both abroad (Ives *et al.*, 2024; Koehrsen and Ives, 2025) and in Brazil (Smith and Veldman, 2020). An example of resistance by forest-dependent communities to agricultural

frontier expansion can even be found in one of the chosen study municipalities for this thesis, Lábrea, where a local Evangelical church pastor and congregation supported successful bottom-up demands for territorial recognition and creation of a RESEX reserve (Aleixo and APADRIT, 2011). Future research could explore how changing religious identities interact and hybridise with traditional Amazonian peasant identification to shape environmental values and cultural expression.

Contrarily, future research might also examine how the spread of evangelical Christianity and historical and contemporary missional activities across the Amazon intersect with changes in biocultural diversity, as is suggested in the results of **Chapter 2.** Moreover, a fruitful research route could be to interrogate the relationship between religion and political ecology. In particular, the links that have been made between Evangelicalism and Jair Bolsonaro's rise to the Brazilian presidency in 2019 (de Sá Guimarães *et al.*, 2023), one that oversaw weakening legislative resistance and enforcement to agricultural expansion in the Amazon (Fearnside, 2018).

A suite of fruitful research possibilities exist: Future work could explore how heterogeneous the beliefs and practices related to the environment are within Brazilian Evangelicalism, or how the in-migration of missionaries and priests from overseas and south and south-eastern Brazil to Amazonia influence the power and politics that play out in the Church and its' impact on environmental beliefs. Moreover, future research could explore how traditional Indigenous religion and spirituality (and the interwoven forest-related identities) interact with dominant Evangelical beliefs. Each of these research avenues would no doubt produce fascinating and important results.

5.4.4 Institutional links between agriculture and cultural dissemination

Another interesting avenue of research that this PhD did not explore is the link between investments in cultural vehicles (such as radio stations) by landowning elites, namely those that are invested in wholesale mechanized agriculture, or *Agronegócio*. Famous examples of politicians who own large plots of agricultural land across Amazonia, such as the current Governor of Pará state, demonstrate that the nature of politics and agribusiness are relatively interlinked across the biome. Moreover, more than 35 investigations into potential corrupt deals between town mayors and local agribusiness executives were launched in 2022 because Sertanejo megastars (such as Gusttavo Lima)

were flying to rural towns to play shows for R$800,000 (over £100,000) to a municipal population of approximately 8,000 people (Pavão, 2022). Future research might explore the relationship between popular culture dissemination at the municipal-level across the Brazilian Amazon, specifically in municipalities that this research identified to show strong cultural affiliations with cattle culture through Sertanejo popularity.

Interestingly, through examples such as those provided above, we observe that political affiliations and agendas can infiltrate the dissemination of popular culture at the municipal scale. Evidence from across Amazonia and Brazil suggests that some landowning elites have aimed to influence popular cultural expression in rural Amazonian municipalities through illegal partnerships with municipal government officials (Pavão, 2022). If, for example, the aim of such cultural interventions were to undermine traditional peasant cultures by stifling playtime of Amazonian musical genres and popularising *Agronejo* (a techno influenced sub-genre of Sertanejo with lyrical content that more conspicuously references becoming a rich cattle rancher and raising cattle than Sertanejo) among rural communities, it would make most sense to do so in municipalities with strong roots in traditional forest-based practices, where cultural resistance to a transition from small-scale family farming to cattle ranching might be strongest.

The links between largescale agribusiness and right-wing political candidates in Brazil, most notably Jair Bolsonaro, is well established (Viana *et al.*, 2016; de Area Leão Pereira *et al.*, 2020; Fearnside and Filho, 2025). Results from **Chapter 2** and **3** of this thesis suggest that cultural expression is entangled with the advancement of agricultural frontiers across Amazonia, particularly towards cattle culture. As was discussed in **Chapter 2**, playtime on local radio stations is subject to local political incumbency and influence (Boas and Hidalgo, 2011), and ultimately, ownership. Future research might explore which social groups represent majority ownership of local radio stations and even compare their findings with the results of **Chapter 2** of this thesis to understand if there are links between radio ownership, political allegiances, and dominant genre playtime or messaging on local radio stations (Belik and Belik, 2021). Perhaps another pertinent direction future research may take would be to obtain information on the prevalence of community owned radio stations and what relationship this has with the diversity of genres played on local radio stations across Amazonia. Surely, this would provide insight into how different power structures impact cultural dissemination across

the Brazilian Amazon and potentially, environmental outcomes, an important yet understudied area of research.

5.4.5 Environmental Governance and Policy Recommendations

Findings from my research have interesting and potentially profound implications for ongoing debates on environmental governance. This research has shown that the tangible expressions of cattle culture (**Chapters 2** and **3**) and relational values towards pasture and cattle are strongest (**Chapter 4**) in more deforested, late-stage frontier setting, while values and cultural expressions related to forests are weakest in these places. Culture is a crucial component in shaping values for nature and land-use behaviours (Hodel, le Polain de Waroux and Garrett, 2024). Culture is also embedded in local institutions, and is expressed in the everyday practices of institutions that structure social and economic life (Ostrom, 1990). This suggests that the efficacy of externally implemented policy instruments (such as PES programs like *REDD+*, or market-based certification schemes like carbon credits) in these frontiers is placed in doubt, perhaps because of a mismatch between federal and local institutional resource management priorities. Specifically, this research suggests that interventions in tropical forest regions need to be connected to the local realities of land-use practicalities and trajectories of environmental change at the meso-regional scale (municipality, in the case of this study) (Scales, 2012). My research suggests that macro-scale policy instruments need to be integrated with local resource governance arrangements in pre- and early frontiers, and in particular, strategies that are grassroots (Aleixo and APADRIT, 2011), place-based (Kenter, 2016), and community owned (Brondizio, 2025; Virtanen *et al.*, 2025). This could open the door to having forested landscapes managed in a more enduring and effective way that is motivated by cultural values and identities that have co-developed with forests, such has been the inspiration for many Indigenous Lands and Extractivist Reserves across Amazonia (Parry *et al.*, 2025). This research could help to inform the development of nuanced policy pathways at local scales that emphasize the importance of cultural or relational values priorities of a variety of landholders. For instance, policy instruments that are co-created with cattle ranchers willing to engage in conservation target setting — such as benchmarking and maintaining minimum soil fertility levels or biodiversity abundance in forest plots neighbouring pasture plots — could make use of RVs mapping for ranchers to ensure effective and lasting interventions. Such an exercise

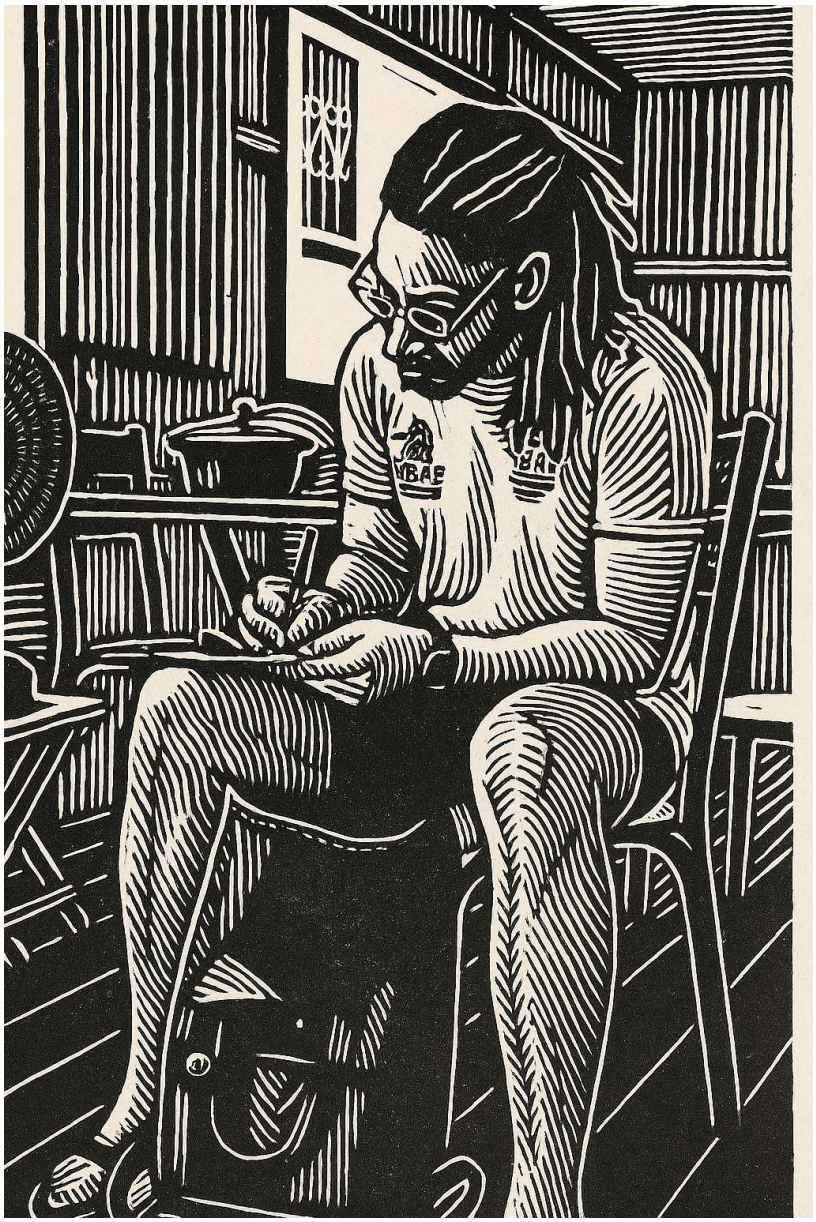
may reveal that the utility value of being able to eat beef on a regular basis is more important to ranchers than identifying with being a rancher of a particular municipality on average, which would open avenues to establish more efficient ways to achieve this while providing better outcomes for the land and making minimal economic sacrifices. Such an approach would likely help to solidify priority targets for species or habitat conservation by providing a more coherent framework for what rural communities across the tropics value and why (Chan *et al.*, 2025).

The findings from this thesis are also relevant to other regions of the tropics undergoing rapid agricultural-driven deforestation. Yuliani *et al.* (2020, 2023) document how overlooking approaches grounded in local values priorities and focusing primarily on economistic approaches can limit local participation in conservation and restoration activities across Indonesia, another country with alarmingly high rates of deforestation. Such examples underscore the importance of macro-level conservation targets that are connected and informed by local realities and priorities (Yuliani *et al.*, 2018; Carmenta, Barlow, *et al.*, 2023). For example, payments-for-ecosystems services are a common form of top-down centrally designed and regulated conservation instrument that financially rewards managers of natural resources (such as farmers) for hitting conservation targets, and is employed across the tropics with mixed results (Martin-Ortega, Ojea and Roux, 2013). Framing, or better yet, co-creating such instruments in ways that resonate with how local communities value or relate to nature could heighten the efficacy of such schemes by encouraging better cooperation from local community members (Lliso *et al.*, 2022). Moreover, by centring the design of such policy instruments in local values, this allows for local ecological knowledge to be integrated into payment plans for land managers more effectively, which can produce better and more holistic ecological outcomes (Kreitzman *et al.*, 2022).

Importantly, this research points to the ramifications that continued forest loss might have for future local resource management. It is possible that because of the distinct cultural identities and values that people who primarily rely on cattle for their livelihoods hold, federal forest conservation targets could meet resistance at the local level, particularly if this is accompanied by anti-cattle rhetoric (Hoelle, Gould and Tauro, 2022). Although this research found that the relational values held for both forests and pasture were relatively concomitant in the early frontier Lábrea, most deforestation activity happens tens of kilometres from urban areas and is often spatially

disconnected from many traditional people that participated in this research (Figure 3.3b, Supplementary Figure 3.1b). Thus, forest conservation actions (whether government-led or community based) need to be aware of and work with the cultural fabric of society (Reed *et al.*, 2019) by being anchored in the values and priorities of forest-proximate people for it to be sustainable and ultimately effective (Gomes *et al.*, 2018; Pereira and Terrenas, 2022; Pratzer *et al.*, 2023). Failure to do so could open the door to this municipality (as well as others across Amazonia at a similar stage of frontier advance) following the trajectories of São Félix and Paragominas in the decades to come.

This thesis represents my attempt to understand how advancing agricultural deforestation frontiers intersect with culture and environmental relational values at large spatial scales. It is my hope that this research contributes to integrating culture into future studies and ultimately, into interventions addressing destructive LULCC – processes that are not only ecologically disastrous but also deepen the marginalisation of the diverse cultures, identities, and livelihoods of forest-dependent people across Amazonia.



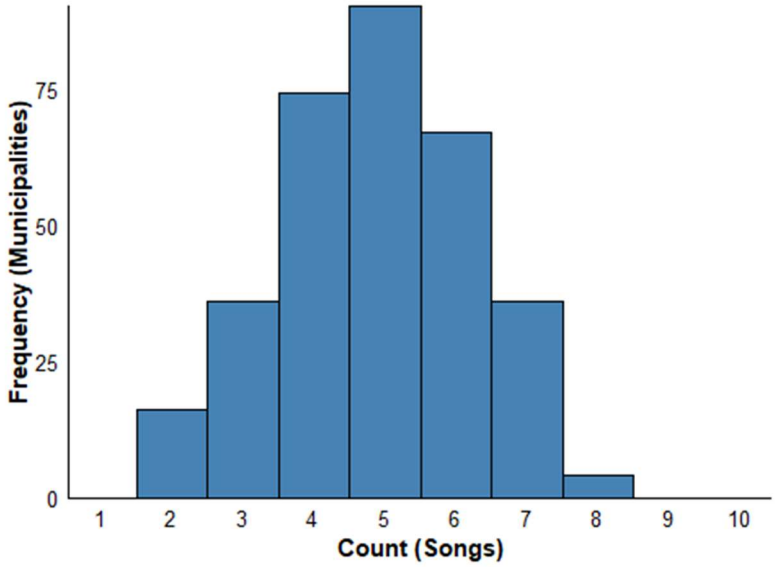
"Just move on up, to a greater day,
With just a little faith you can put your mind to it,
You can surely do it."

(Curtis Mayfield, 'Move On Up', 1970)

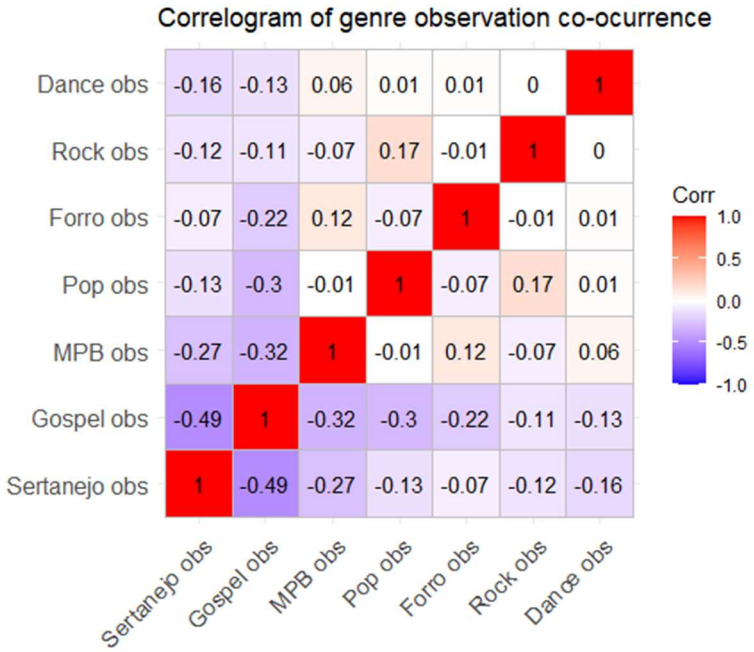
Appendices

Chapter 2 Supplementary Materials

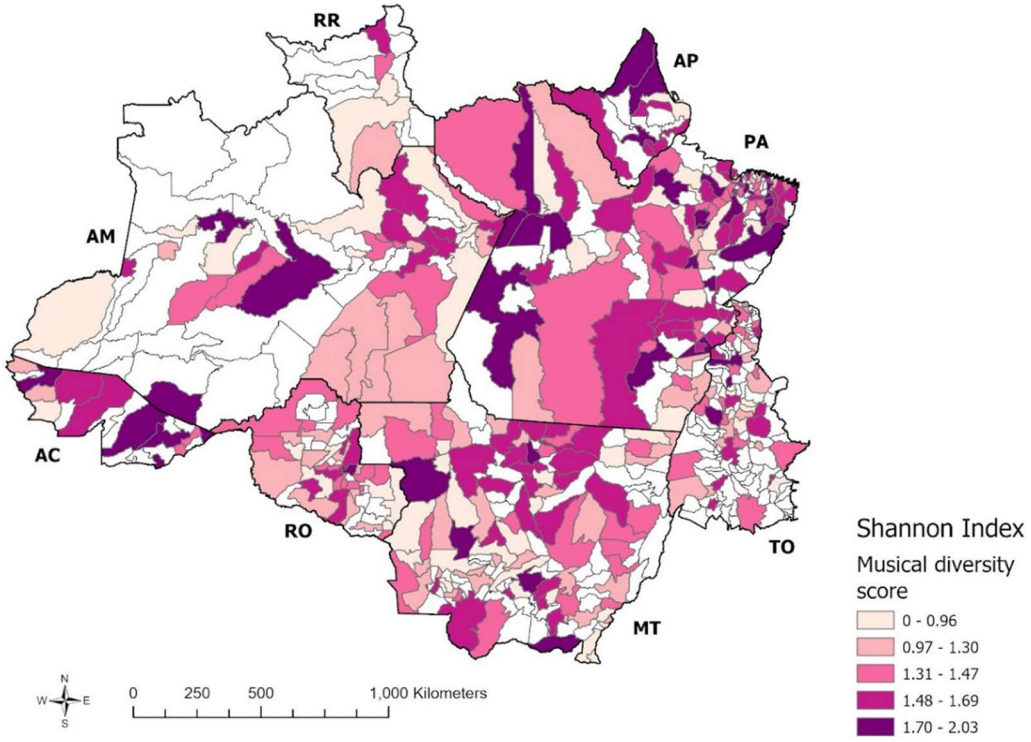
Supplementary Figure 2.1. Histogram of unique genre counts at municipality scale



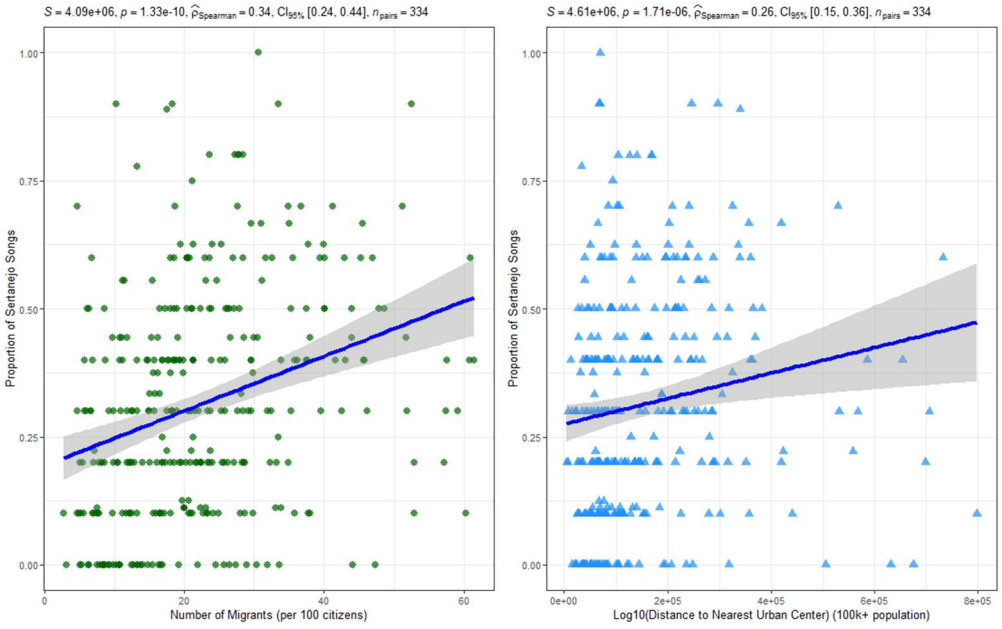
Supplementary Figure 2.2. Correlogram of musical genres identified from online radio stations in 335 municipalities in the Brazilian Amazon.



Supplementary Figure 2.3. Shannon index scores per municipality based on musical diversity, where higher Shannon index scores refer to higher diversity. *Corresponding state acronyms are shown adjacent to the state highlighted by the thicker black line (e.g. AM for Amazonas). Blank municipalities (white with faint borders) represent municipalities with missing data, or insufficient data collected (<8 songs).*



Supplementary Figure 2.4. Scatterplot showing the correlations between the proportion of Sertanejo songs recorded per municipality, and (a) the Number of migrants per 100 citizens; and (b) the Log Euclidean distance to the nearest municipal capital of at least 100,000 inhabitants. *Lines of best fit are indicted in blue, with 95% confidence intervals are indicated by grey shading around slope.*



Supplementary Table 2.1. Number of songs observed per unique genre observed across data collection in all municipalities (n = 3245 songs; 33 unique genres).

Genre	Number of Songs	% of Total Songs
Sertanejo	1015	31.28
Gospel	684	21.08
MPB	444	13.68
Pop	327	10.08
Forró	183	5.64
Rock	105	3.24
Dance	93	2.87
Pagode	74	2.28
Latino	52	1.60
Alternative	44	1.36
World	42	1.29
RnB	35	1.08
Rap	24	0.74
Samba	22	0.68
Reggae	17	0.52
Brazilian	12	0.37
Axe	11	0.34
Baile Funk	10	0.31
American Country	9	0.28
Jazz	9	0.28
Folkloric	4	0.12
Metal	4	0.12
Salsa	4	0.12
Calypso	3	0.09

Disco	3	0.09
Blues	2	0.06
Brega	2	0.06
Folk	2	0.06
Soul	2	0.06
Christmas	1	0.03
Electronic	1	0.03
Neo-Soul	1	0.03

Supplementary Table 2.2. Number and Percentage of Survey Respondents (See Chapter 3 (Culture) that listen to local radio stations at least 'some of the time' (responded '3 = Sometimes'; '4 = Often'; '5 = All The Time'.

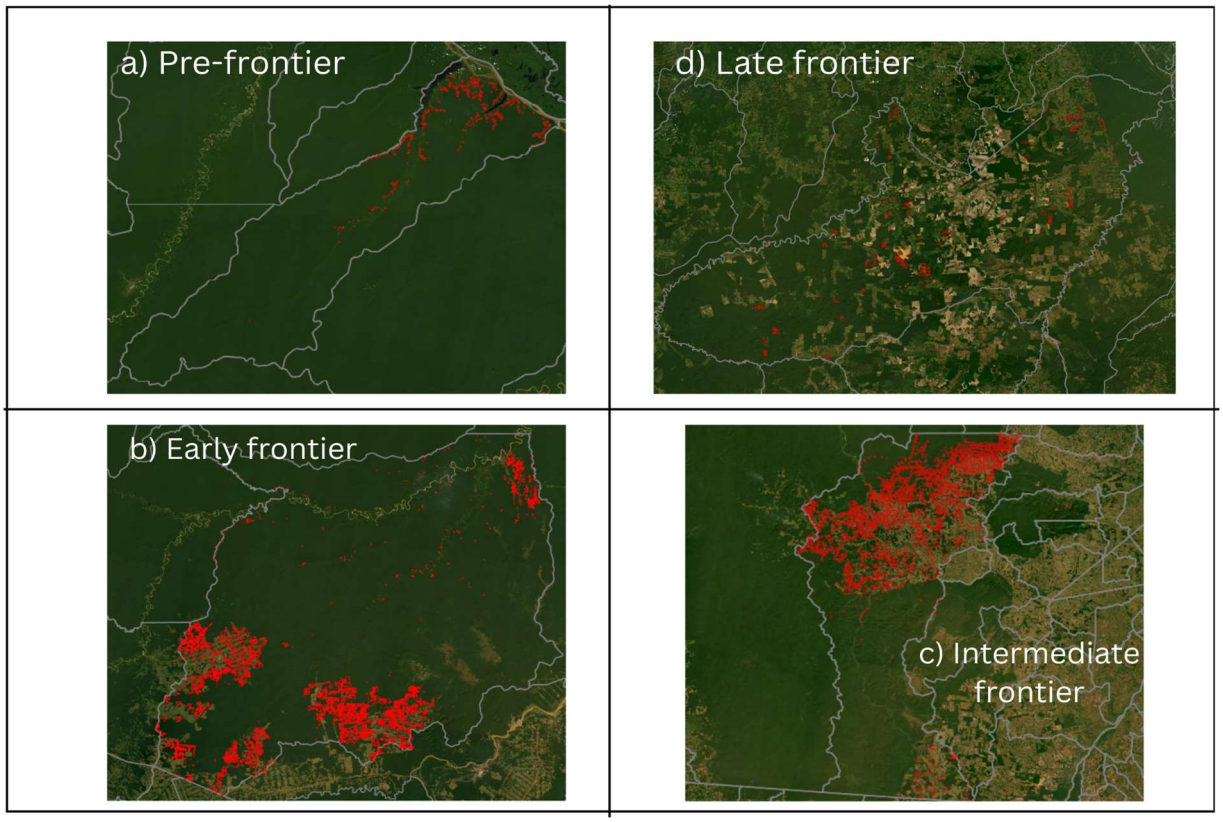
Response to Question '*I listen to the local radio…*'	**Number of Responses**	**% of All Interviewees (Rounded to nearest whole percent)**
Often (*4*)	74	18%
All the time (*5*)	72	18%
Total	*269*	*65%*

Supplementary Table 2.3. Self-reported Religious Identity of Survey Respondents (See Chapter 3 (Culture)) that listen to Gospel Music often (responded '4 = Often'; or '5 = All The Time'), and the average Likert score given by these respondents for all other musical genres in that case.

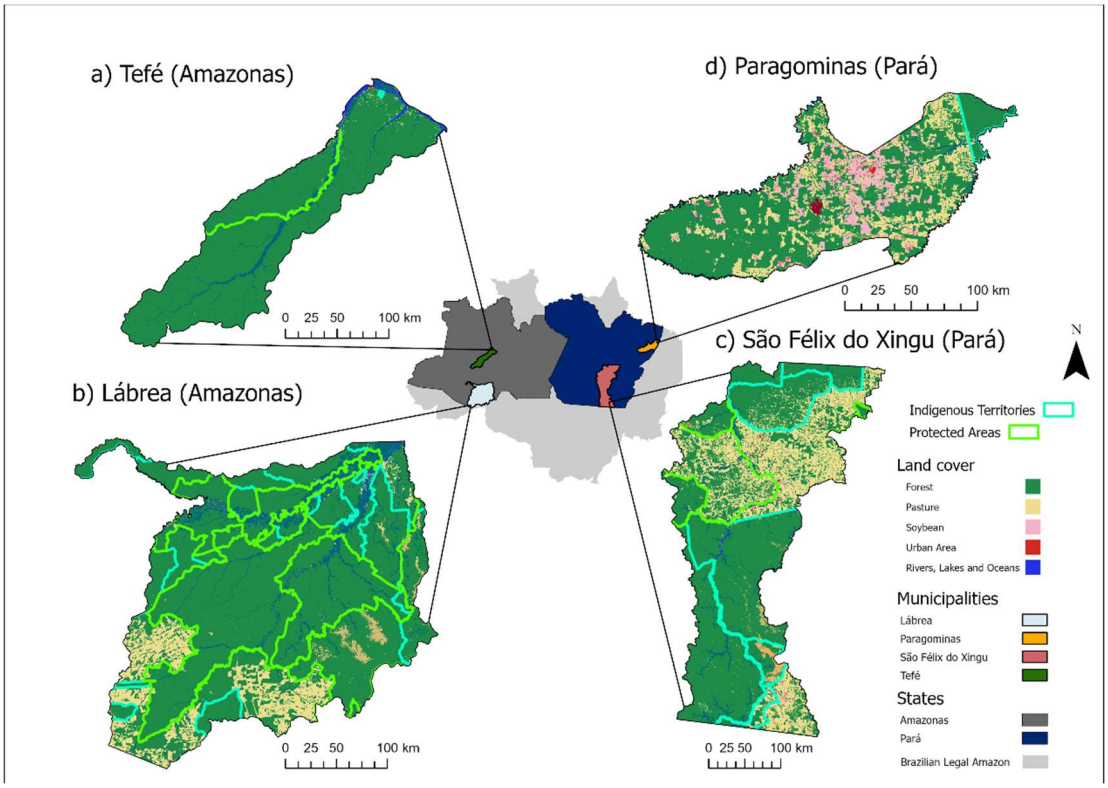
Response to Question '*I listen to the local radio…*'	**Most common religious identity (% of total respondents)**	Average likert response for all other musical genres
Often (*4*)	Evangelical (50%)	2 (Not often)
All the time (*5*)	Evangelical (62%)	2 (Not often)

Chapter 3 Supplementary Materials

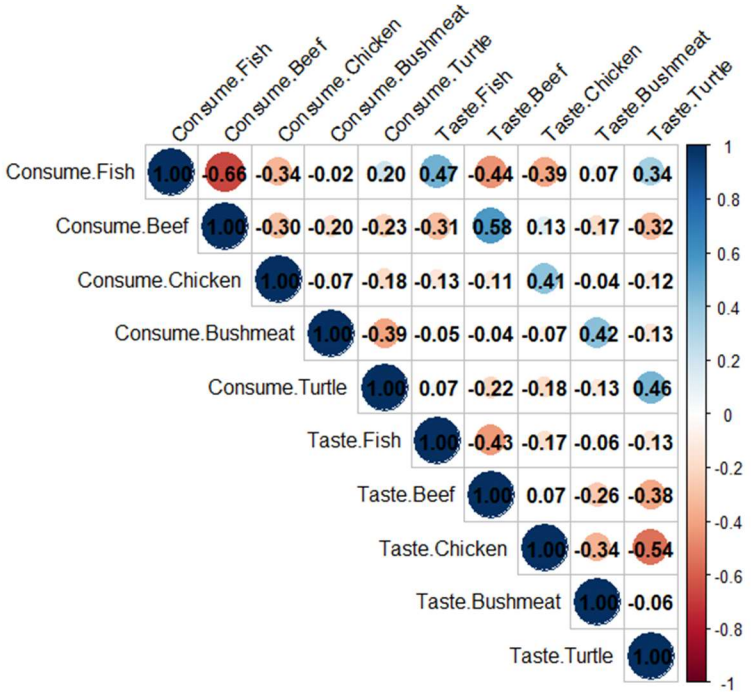
Supplementary Figure 3.1. Recent deforestation activity (2019-2024) across each municipality: a) Pre-frontier (Tefé, Amazonas; top left); b) Early frontier (Lábrea, Amazonas; bottom left); c) Intermediate frontier (São Félix do Xingu, Pará; bottom right); and d) Late frontier (Paragominas, Pará; top right). Satellite imagery taken from MapBiomas Alertas platform: https://plataforma.alerta.mapbiomas.org/ (28th August, 2025).



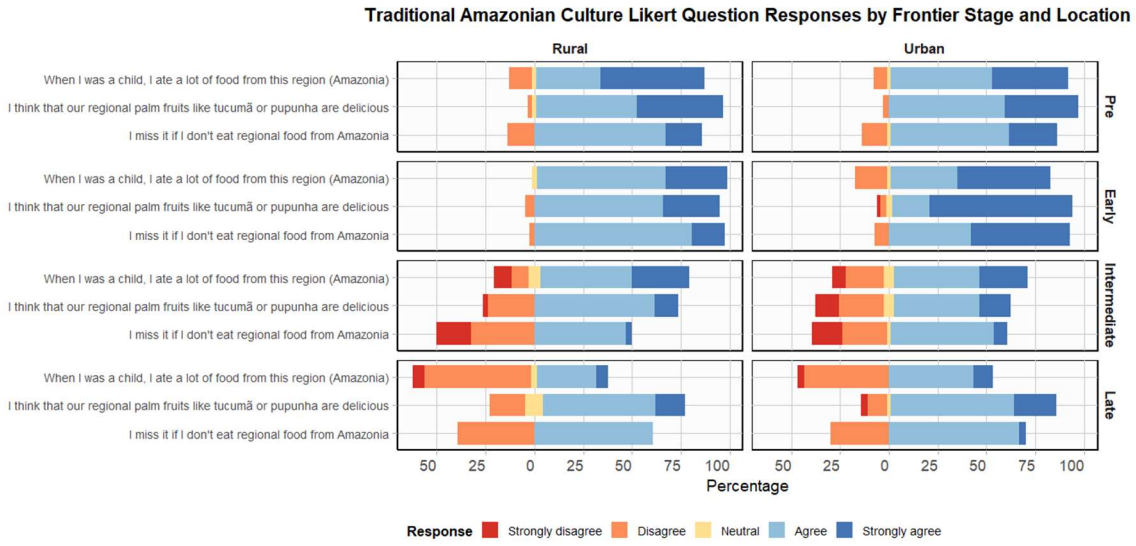
Supplementary Figure 3.2. Location of the study regions in Brazilian Legal Amazon, municipalities and detailed land-cover information of each municipality where surveys were undertaken, indicating the location of Conservation Units (UC) and Indigenous Territories (TI) in each municipality. *Forest cover is indicated in green, converted land (pasture) in yellow, water bodies in blue, soy plantations in pink and urban areas in bright red. Municipality is highlighted within the state in a smaller regional map in the centre of the page.*

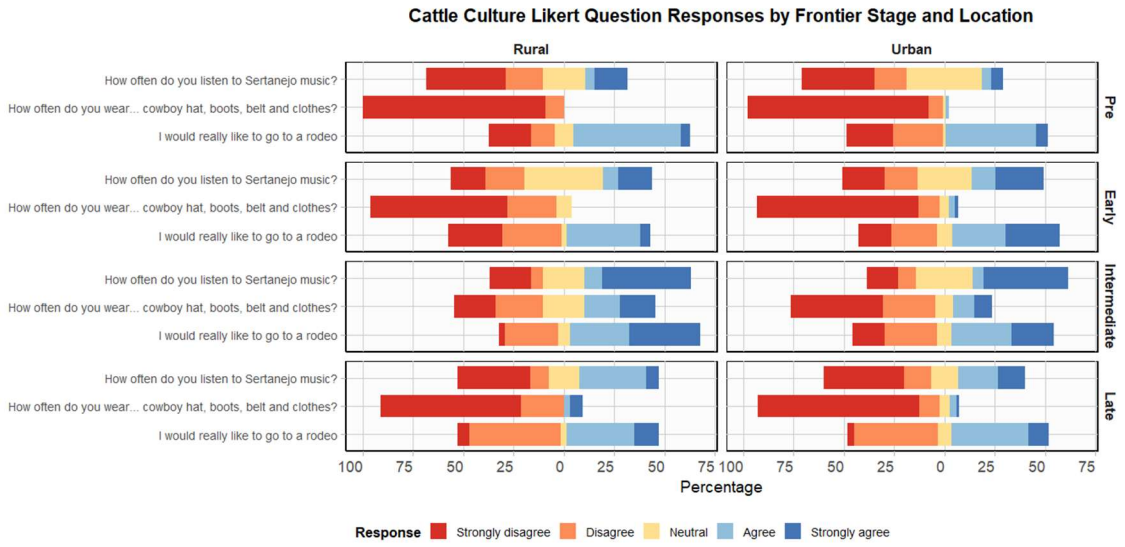


Supplementary Figure 3.3. Correlogram of Food Protein Consumption and Taste rankings by respondents



Supplementary Figure 3.4. Traditional Amazonian factor and cattle culture factor questions and response frequencies from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages.





Supplementary Table 3.1. Survey questions for Section 1) Socio-economic and demographic characteristics; and Section 2) cultural expression survey questions.

	Question (Cultural expression type):	**Question Type**
Section 1	**1) What is your?** 1. Name 2. Age 3. Sex	**Open Ended**
	2) Where where you born? 1. Municipality 2. State	**Open Ended**
	2a) Were you raised in a rural area?	**Yes/No**
	3) How do you identify? 1. River Dweller 2. Colonist farmer 3. Indigenous 4. Quilombola 5. Rancher 6. Settler 7. Soy Producer 8. Small-scale Rural Producer 9. Small-Scale Family Agricultural Farmer 10. Other (please specify) 11. None of these	**Multiple Choice**
	4) Which year of formal education have you completed up until now (plus until which grade)? 1. Never studied	**Multiple Choice**

	2. Literacy *Alfabetização* 3. Primary School *Fundamental* 4. Middle School Ensino Médio 5. High School *Ensino Superior* 6. Adult Primary Education School *EJA* 7. Other (please specify) **5) What is your religion?** 1. No religion 2. Catholic 3. Evangelical 4. Other (please specify) **6) What is your main job?** **7) Where do you work?** **8) Do you have a second job?** **9) How many people live in this home?** **10) How many smartphones do you have in this home?** **11) How many radios do you have in this home?** **12) How many computers/laptops do you have in this home?** **13) Which of these vehicles do you own (how many of each, and from which model and make are they)?** 1. Car 2. Motorbike 3. Canoe with motor 4. Speedboat 5. Other	**Multiple Choice** **Open Ended** **Open Ended** **Open Ended** **Open Ended** **Open Ended** **Open Ended** **Open Ended** **Multiple Choice**
Section 2 (Culture)	**How often do you listen to** (Music); 1. Sertanejo? 2. Gospel? 3. MPB? 4. Forró? 5. Rock? *6. Pagode?** 7. Samba? 8. Brega/Tecnobrega? 9. Carimbó? *10. Folkloric?**	**Likert scale;** 1 = Never listen to 5 = Always listen to **Yes/No**

	Do you generally wear (Clothing): 1) Cowboy Hat? (Y/N) 2) Cowboy/Leather Boots? (Y/N) 3) Country clothing? (Y/N) 4) Belt with Belt Buckle? (Y/N) **How would you classify these types of animal protein in terms of** (Food)**:** **a) Consumption Frequency:** Fish, Beef, Chicken, Bushmeat & Turtle **b) Taste/Preference:** Fish, Beef, Chicken, Bushmeat & Turtle **Please respond on a scale of 1 - 5** (Amazonian cultural norms/practices): 1. I miss typical Amazonian food if I don't eat it 2. When I was a child, I ate lots of typical Amazonian food 3. Eating Acai 'pure' with maybe just a little bit of sugar is delicious! 4. I think the regional fruits of Amazonia (such as Tucumã or Pupunha) are delicious 5. If I were to sleep multiple nights in a row in a hammock it wouldn't bother me 6. I feel comfortable traveling between places in a canoe 7. I would really like to go to a rodeo	**Rank (1-5 for both a & b)** **Likert Scale;** 1 = Completely Disagree 5 = Completely Agree

Supplementary Table 2. Exploratory factor analysis (EFA) model comparisons for both four and six factor models, with factor loadings for each survey item (and significant factor loadings highlighted in bold) provided in the middle column. Model fit indices provided in 'Model' column, underneath model name. Root Mean Square of Residuals (RMSR) < 0.08 indicates 'good' model fit, and Fit based upon off diagonal values >0.9 considered 'good' fit, and closer to 1 = 'excellent' fit.

Model	**Item loadings**			
3-Factor		Factor 1	Factor 2	Factor 3
RMSR = 0.05	Music.Sertanejo	0.35	-0.03	**0.73**
	Music.Gospel	-0.09	0.09	0.02
	Music.MPB	**0.61**	0.08	0.21
	Music.Forro	**0.49**	0.23	**0.51**

Corrected RMSR = 0.07 Fit based upon off diagonal values = 0.97	Music.Rock	**0.81**	-0.21	-0.21	
	Music.Pagode	**0.77**	0.08	0.13	
	Music.Samba	**0.79**	0.06	0.07	
	Music.Brega	**0.57**	0.12	0.32	
	Music.Carimbo	**0.79**	-0.19	-0.01	
	Music.Folkloric	**0.72**	0.16	-0.07	
	Culture.FaltaComida	0.01	**0.56**	0.03	
	Culture.ComidaTipica	-0.01	**0.75**	-0.08	
	Culture.AcaiPuro	-0.14	**0.52**	0.18	
	Culture.FrutasRegionais	-0.02	**0.70**	-0.12	
	Culture.DormirRede	0.11	0.31	-0.14	
	Culture.ViajarCanoa	0.11	0.39	-0.15	
	Culture.Rodeo	0.07	-0.04	0.36	
	clothing_likert	-0.12	-0.16	**0.50**	
4-Factor		Factor 1	Factor 2	Factor 3	Factor 4
RMSR = 0.04 Corrected RMSR = 0.06 Fit based upon off diagonal values = 0.98	Music.Sertanejo	0.19	-0.07	**0.47**	**0.55**
	Music.Gospel	-0.03	0.10	0.11	-0.11
	Music.MPB	**0.51**	0.07	0.13	0.26
	Music.Forro	0.18	0.20	0.12	**0.79**
	Music.Rock	**0.85**	-0.20	-0.07	-0.13
	Music.Pagode	**0.78**	0.09	0.20	0.08
	Music.Samba	**0.78**	0.07	0.13	0.07
	Music.Brega	0.29	0.08	-0.04	**0.67**
	Music.Carimbo	**0.68**	-0.20	-0.08	0.20
	Music.Folkloric	**0.60**	0.16	-0.16	0.22
	Culture.FaltaComida	-0.04	**0.57**	-0.03	0.14
	Culture.ComidaTipica	-0.12	**0.76**	-0.21	0.20
	Culture.AcaiPuro	-0.18	**0.53**	0.13	0.14
	Culture.FrutasRegionais	-0.06	**0.72**	-0.14	0.05
	Culture.DormirRede	0.15	0.34	-0.04	-0.13
	Culture.ViajarCanoa	0.17	**0.42**	-0.02	-0.15
	Culture.Rodeo	0.12	-0.04	**0.49**	0.02
	clothing_likert	-0.09	-0.17	**0.61**	0.07

Supplementary Table 3. List of respondents (total numbers and percentages of total responses) that were born in the same municipality they currently live in, born elsewhere in the same state, born in a different Amazonian statea, and finally, born outside of the legal Amazon.

Municipality	**Born in that municipality**	**Born in another municipality in same state**	**Born in another Amazonian state**	**Born in state outside of Amazonia**	**Total surveys conducted**

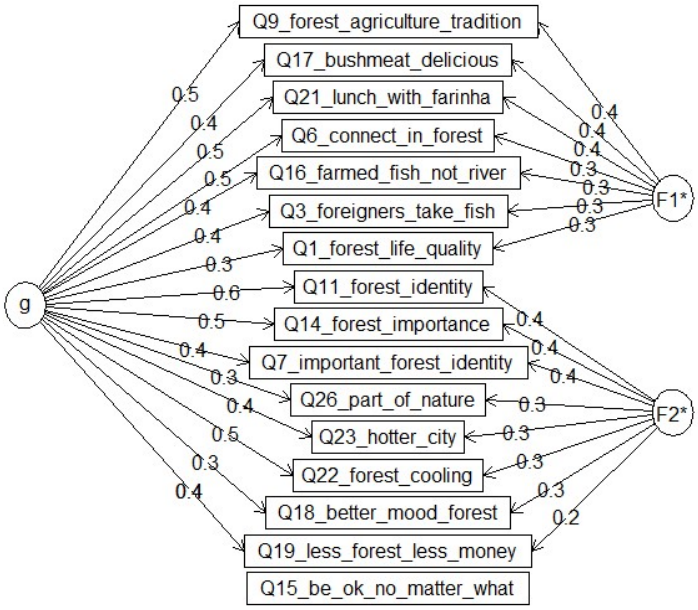
Tefé (pre-frontier)	61 (54%)	49 (44%)	2 (2%)	0 (0%)	108
Lábrea (early frontier)	92 (85%)	16 (15%)	0 (0%)	0 (0%)	112
São Félix do Xingu (intermediate frontier)	17 (18%)	23 (25%)	28 (30%)	25 (27%)	93
Paragominas (Late frontier)	18 (19%)	34 (37%)	29 (31%)	12 (13%)	93

Supplementary table 4. Top five municipalities of origin for all respondents per frontier stage (municipality).

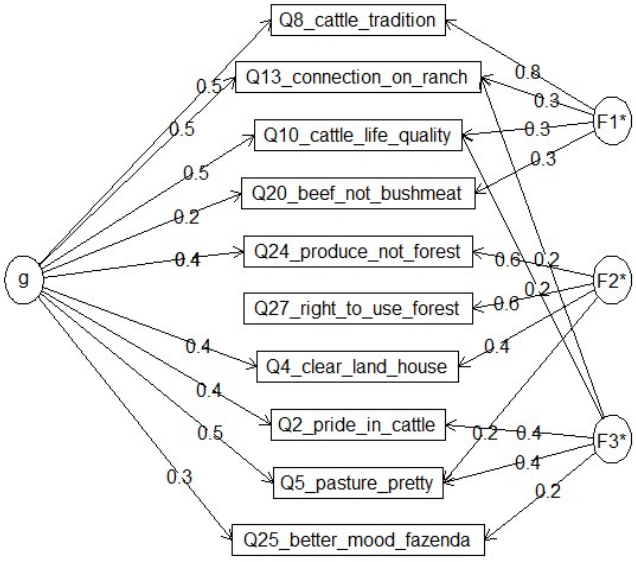
Study Municipality	**Top 5 Places of Origin of Interviewed Participants: Municipality, State (n)**
Tefé (pre-frontier)	Tefé, Amazonas (61); Maraa, Amazonas (11); Alvaraes, Amazonas (5); Carauri, Amazonas (5); Manaus, Amazonas (5)
Lábrea (early frontier)	Lábrea, Amazonas (92); Pauini, Amazonas (7); Canutama, Amazonas (5); Manaus, Amazonas (3); Tapaua, Amazonas (1)
São Félix do Xingu (intermediate frontier)	São Félix do Xingu, Pará (16); Altamira, Pará (3), Marabá, Pará (3); Goiânia, Goiás (2); Goianésia, Goiás (2); Rio Maria, Pará (2); Xinguara, Pará (2); Araguaína, Tocantins (2)
Paragominas (Late frontier)	Paragominas, Pará (18); Bragança, Pará (4), Capitão Poço, Pará (4); Belem, Pará (3); Cândido Mendes, Maranhão (2); Carutapera, Maranhão (2); Monção, Maranhão (2); Pinheiro, Maranhão (2); Garrafão do Norte, Pará (2); Irituia, Pará (2); Ourém, Pará (2); São Domingos do Capim, Pará (2)

Chapter 4 Supplementary Materials

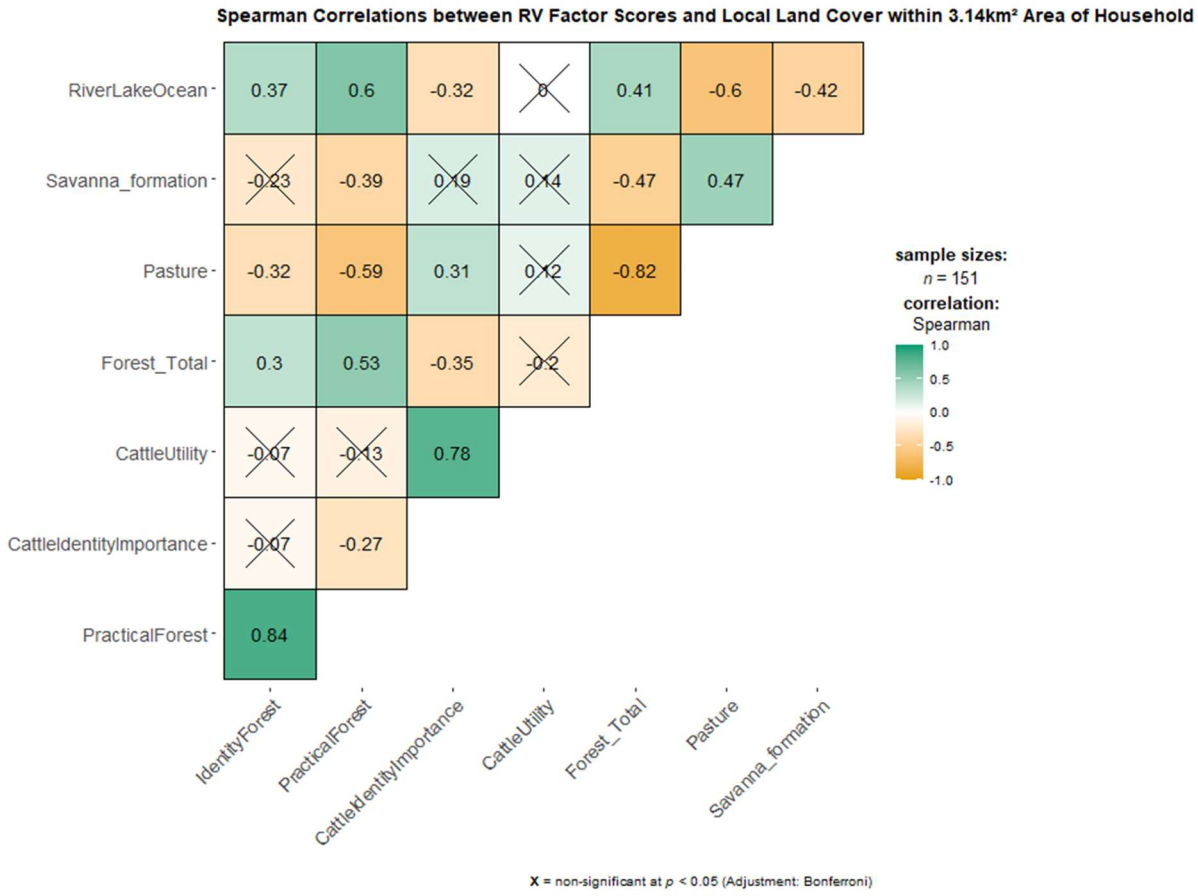
Supplementary Figure 4.1. Two-Factor omega model for PFRV, showing relation of individual survey items to underlying latent construct 'g', and then weightings to each factor in the data (F1, F2).



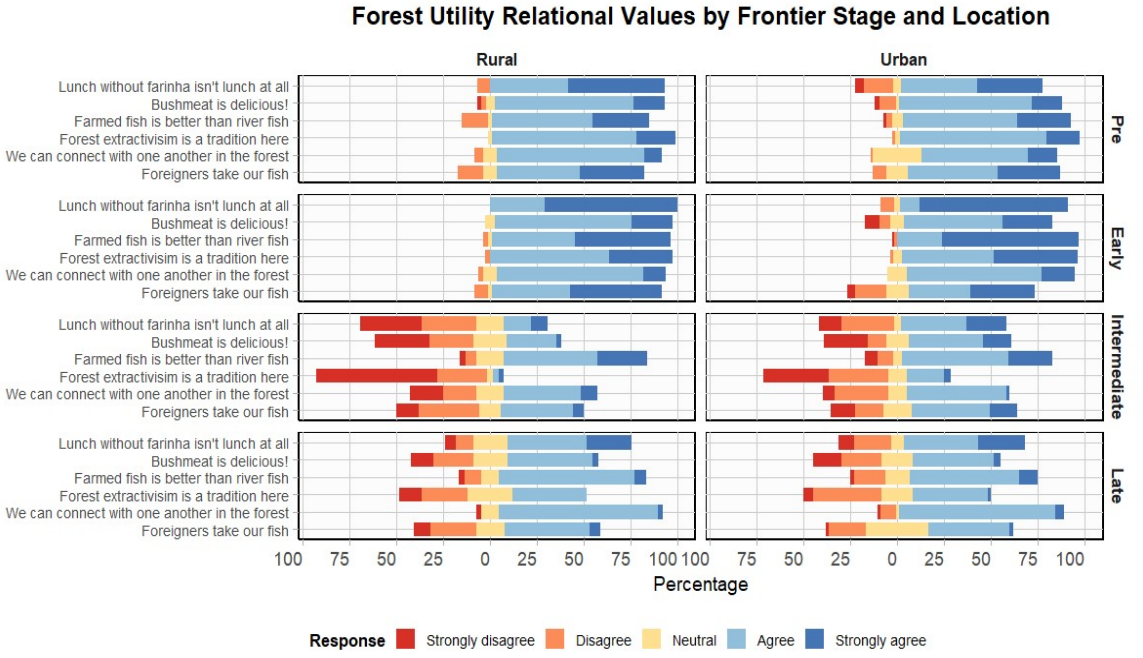
Supplementary Figure 4.2. Three-Factor omega model for PCRV, showing relation of individual survey items to underlying latent construct 'g', and then weightings to each factor in the data (F1,F2, F3).

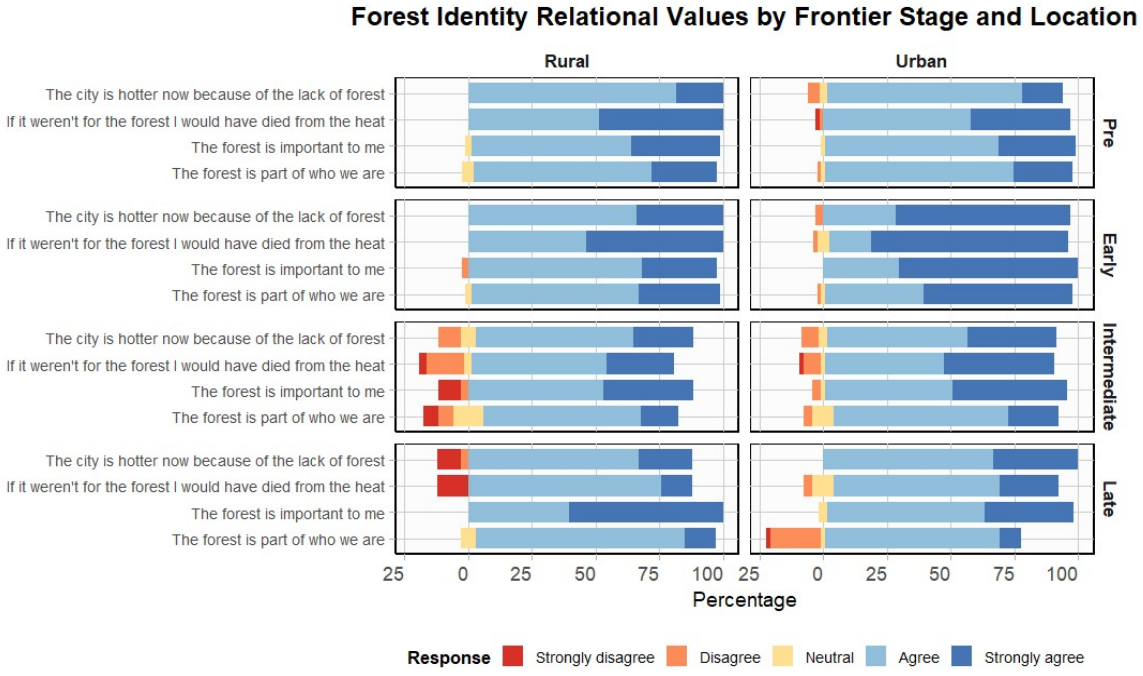


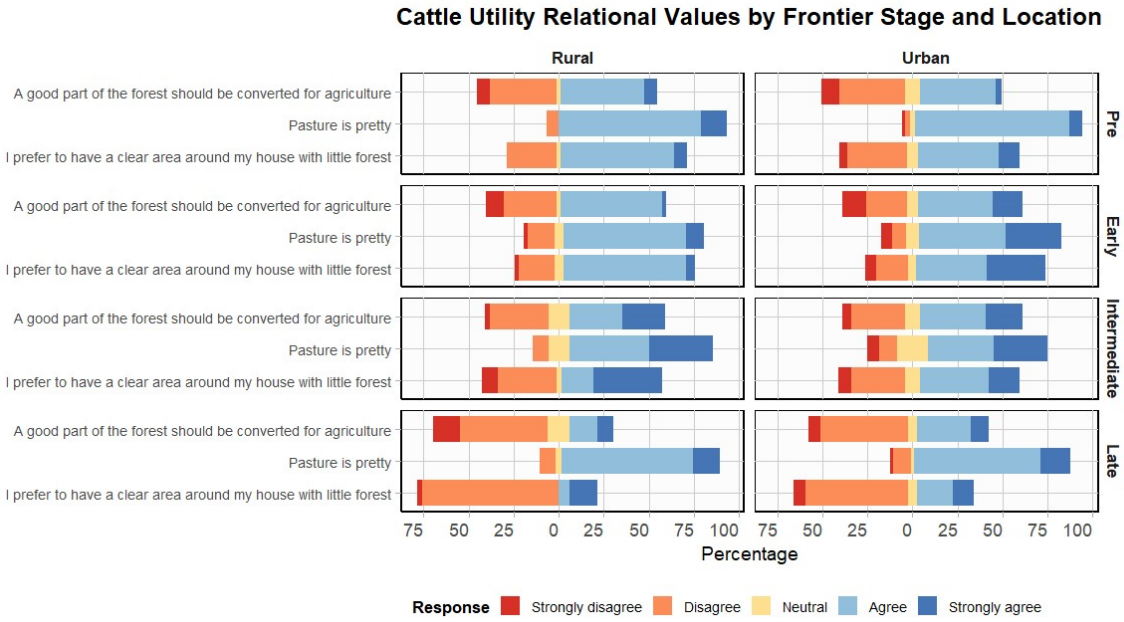
Supplementary Figure 4.3. Spearman correlations between relational values factor scores and local land-use cover within a 3.14km² area around rural survey households (using Bonferroni adjustment method for multiple tests of significance). *Darker green indicates closer to perfect linear correlation (1.0), while darker orange indicates closer to perfect negative correlation (-1.0). Non-significant correlations are indicated with an 'X' over the correlation coefficient.*

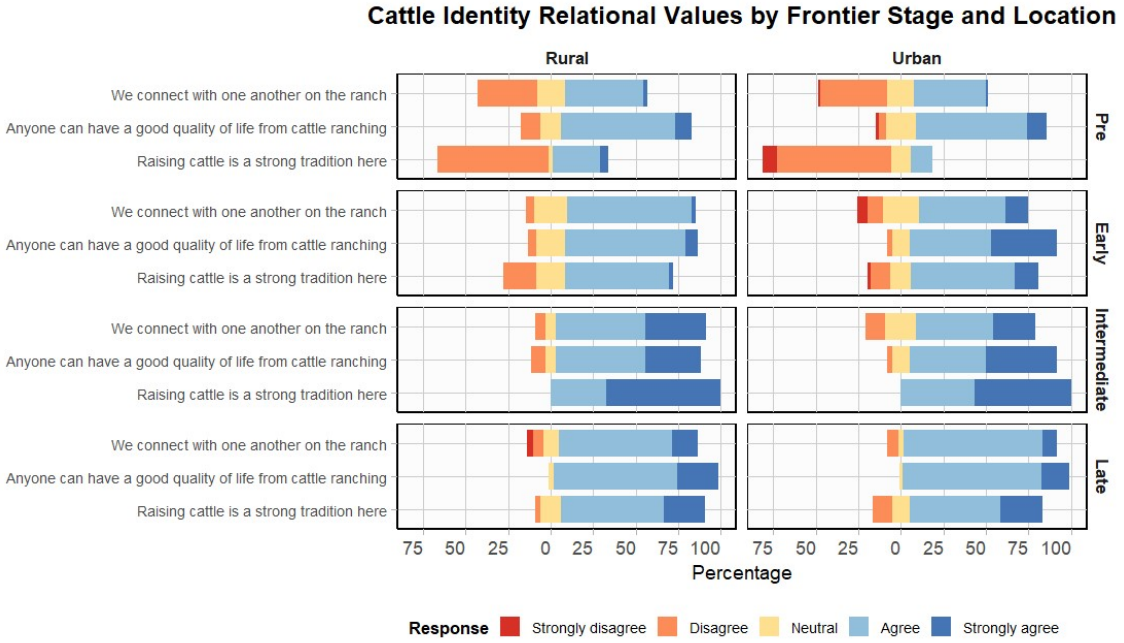


Supplementary Figure 4.4. Pro-forest utility, identity and pro-cattle utility, identity associated RVs questions and response frequencies from 'Completely Disagree (1)' to 'Completely agree (5)', split by rural and urban frontier stages.

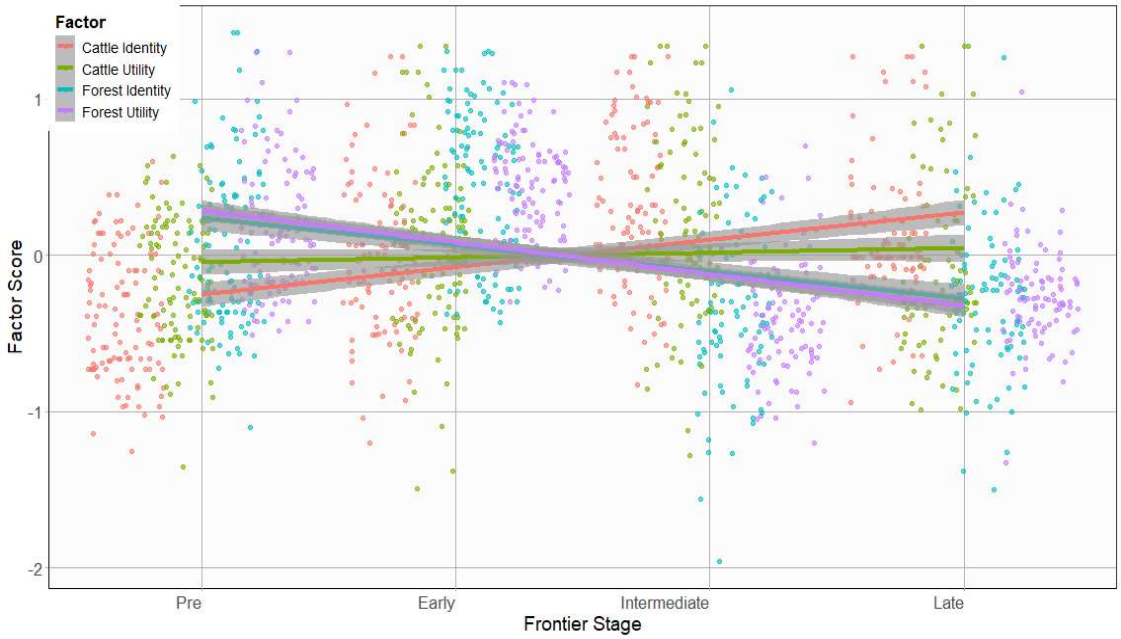




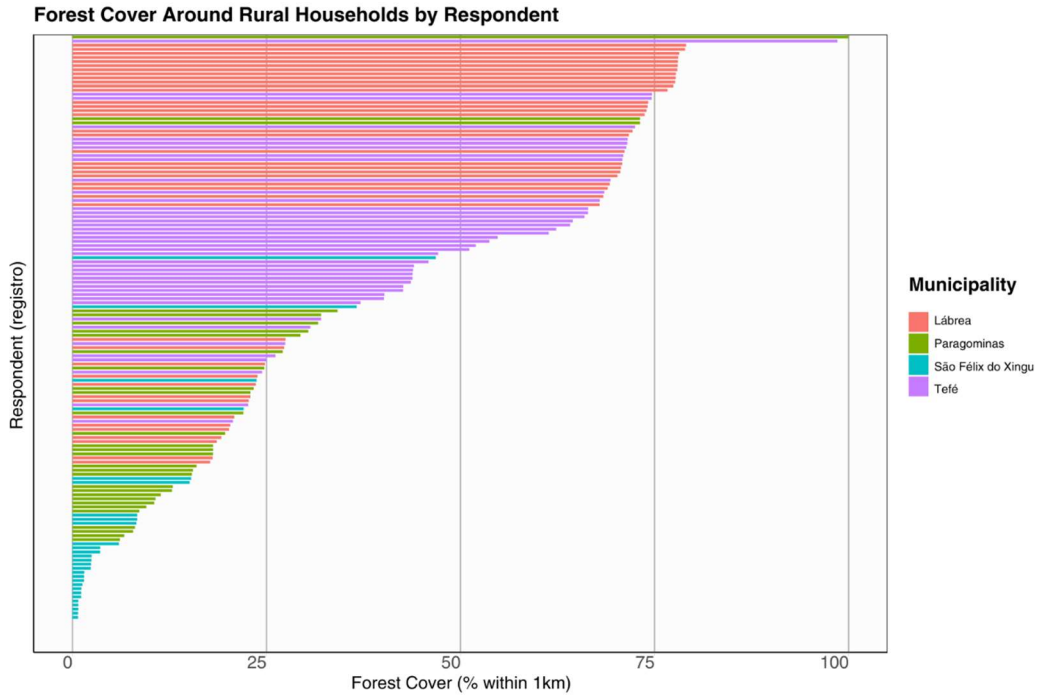

Cattle Utility Relational Values by Frontier Stage and Location
Rural
Urban
A good part of the forest should be converted for agriculture
Pasture is pretty
I prefer to have a clear area around my house with little forest
Pre
Early
Intermediate
Late
75 50 25 0 25 50 75 100
Percentage
Response
Strongly disagree
Disagree
Neutral
Agree
Strongly agree


Cattle Identity Relational Values by Frontier Stage and Location
Rural
Urban
We connect with one another on the ranch
Anyone can have a good quality of life from cattle ranching
Raising cattle is a strong tradition here
Pre
Early
Intermediate
Late
75 50 25 0 25 50 75 100
Percentage
Response
Strongly disagree
Disagree
Neutral
Agree
Strongly agree

Supplementary Figure 4.5. Linear model predictions showing variation in Forest Utility, Forest Identity, Cattle Utility, and Cattle Identity factors across the deforestation frontier stages. *Lines represent fitted values and points represent observed mean scores. Both pro-forest values factor scores tend to decrease toward later stages, while both pro-cattle values factor scores show opposite patterns.*



Supplementary Figure 4.6. Forest cover (as a percentage of total land cover) within a 1km radius of rural surveyed households (n = 151), colour coded by municipality where survey was conducted.



Supplementary Table 4.1. Subscale groupings of survey questions for Pro-Forest and Pro-Cattle RV survey questions. Items in table written in italic (with asterisk) were reverse coded because they measure the opposite direction e.g. Answering 5, or 'completely agree' to Q15 would indicate a lack of RV for forests, so this was reverse coded to make cardinality throughout all questions in the same subscale consistent.

Subscale	Pro-Forest (n = 16)	Pro-Cattle (n = 10)
Questions	Q1) People who work in the forest have a good quality of life; Q3) Outsiders take fish of Ribeirinhos; Q6) People who work in the forest have the chance to connect with others; Q7) The forest says something important about us as a people; Q9) Working in the forest has more tradition here than cattle ranching; Q11) The forest is an important part of my identity; Q14) The forest is very important to me; *Q15) Whatever happens with the rainforest, we, the people will be ok;** *Q16) Farmed fish is better to eat than fish from the river;** Q17) Bushmeat is delicious!; Q18) When I'm angry or upset I go and spend time in the forest, by the river or lake to feel better; Q19) If the forest around here got cut down, people would have less option to earn money;	Q2) I would take great pride in raising cattle; Q4) I prefer to have a clear area around my house with little forest; Q5) I think that pasture is pretty; Q8) We have a strong tradition of cattle ranching; Q10) Anyone that owns cattle can have a good quality of life; Q13) People that work on a ranch have the chance to connect with others; Q20) Beef is better to eat than bushmeat; Q24) It would be good if a large part of the Amazon rainforest were converted into productive agricultural land; Q25) When I'm angry or upset I go and spend time at a ranch to feel better; Q27) People have the right to use the forest the way they see fit

	Q21) A lunch without farinha isn't really a lunch; Q22) If it weren't for the forest close by i would have already died by now; Q23) The city is hotter now because there is less forest and more asphalt; Q26) I see the natural world as a community that I play a part in	
Excluded Question: Q12) This land is mine, no one can take me from it		

Supplementary Table 4.2. One-Factor vs Multi-Factor Confirmatory Factor Analysis model comparisons with included survey items, factor loadings and model fit indices for PFRV & PCRV subscale models.

Model	**Items retained in final model; Corresponding Factor & Factor Loadings**	**Model fit indices**
One-Factor Forest CFA (7 items retained)	<u>General Factor</u> Q3_outsiders_take_fish 0.57 Q6_connect_in_forest 0.59 Q9_forest_agriculture_tradition 0.63 Q11_forest_identity 0.61 Q14_forest_importance 0.51 Q21_lunch_with_farinha 0.63 Q22_forest_cooling 0.54	RMSEA - 0.088 (**poor**) Robust RMSEA - 0.100 (**poor**) SRMR = 0.058 **(good**) Robust CFI - 0.902 (**acceptable**) Robust TLI -

		0.854 (**poor**)
Two-Factor Forest CFA (10 items retained)	Factor 1 / Factor 2 Q3_outsiders_take_fish 0.56 Q6_connect_in_forest 0.57 Q9_forest_agriculture_tradition 0.65 Q11_forest_identity 0.70 Q14_forest_importance 0.57 Q16_farmed_fish_not_river 0.59 Q17_bushmeat_delicious 0.54 Q21_lunch_with_farinha 0.64 Q22_forest_cooling 0.66 Q23_hotter_city 0.56	RMSEA - 0.066 (**acceptable**) Robust RMSEA - 0.078 (**acceptable**) SRMR = 0.052 (**good**) Robust CFI - 0.958 (**excellent**) Robust TLI - 0.884 (**close to acceptable**)
One-Factor Cattle CFA (6 items retained)	General Factor Q4_clear_land_house 0.53 Q5_pasture_pretty 0.53 Q8_cattle_tradition 0.58 Q10_cattle_life_quality 0.58 Q13_connection_on_ranch 0.73 Q24_produce_not_forest 0.56	RMSEA - 0.157 (**poor**) Robust RMSEA - 0.151 (**poor**) SRMR = 0.077 (**acceptable**) Robust CFI - 0.895 (**close to acceptable**)

		Robust TLI - 0.726 (**poor**)
Three-Factor Cattle CFA (9 items retained)	<u>Factor 1</u> <u>Factor 2</u> <u>Factor 3</u> Q2_pride_in_cattle 0.48 Q4_clear_land_house 0.61 Q5_pasture_pretty 0.67 Q8_cattle_tradition 0.61 Q10_cattle_life_quality 0.63 Q13_connection_on_ranch 0.79 Q24_produce_not_forest 0.82 Q25_better_mood_fazenda 0.42 Q27_right_to_use_forest 0.50	RMSEA - 0.096 (**poor**) Robust RMSEA - 0.102 (**poor**) SRMR = 0.065 (**acceptable**) Robust CFI - 0.873 (**poor**) Robust TLI - 0.809 (**poor**)
Two-Factor Cattle CFA	<u>Factor 1</u> <u>Factor 2</u> Q4_clear_land_house 0.63 Q5_pasture_pretty 0.62 Q8_cattle_tradition 0.62 Q10_cattle_life_quality 0.63 Q13_connection_on_ranch 0.78 Q24_produce_not_forest 0.64	RMSEA - 0.077 (**acceptable**) Robust RMSEA - 0.085 (**close to acceptable**) SRMR = 0.041 (**excellent**) Robust CFI - 0.954 (**excellent**)

		Robust TLI - 0.913 (**acceptable**)

Supplementary table 4.3. Kruskal-Wallis non-parametric test for significant differences between medians of factor scores across frontier stage (Municipality). Significant differences highlighted in bold with * (p <0.05), ** (p <0.01), or *** (p < 0.001).

Factor (KW Test statistic, df = 3)	**p-value**
Forest Practicality Values Factor Scores (KW Chi-sq = 205.59, df = 3)	**< 0.001 *** **
Forest Identity Values Factor Scores (KW Chi-sq = 114.93, df = 3)	**< 0.001 *** **
Forest Identity Values Factor Scores (KW Chi-sq = 90.37, df = 3)	**< 0.001 *** **
Forest Identity Values Factor Scores (KW Chi-sq = 22.43, df = 3)	**< 0.001 *** **

Supplementary table 4.4. Dunn (1964) Kruskal-Wallis multiple comparison Z-scores, p-values, and p-adjusted with Bonferroni correction. Results shown in order of (1) Forest Utility Factor; (2) Forest Identity Factor; (3) Cattle Identity & Importance Factor; and (4) Cattle Utility Factor. Significance levels indicated with * = <0.05, ** <0.01, *** <0.001.

Comparison	***Z***	***p-value raw***	***Adjusted p-value (Bonferroni)***
Pre – Early	(1) 4.35 (2) 5.32	(1) <0.001 *** (2) <0.001 *** (3) <0.001 ***	(1) <0.001 *** (2) <0.001 ***

	(3) 5.37 (4) 2.83	(4) 0.005**	(3) <0.001 *** (4) 0.028*
Pre – Intermediate	(1) -8.59 (2) -4.15 (3) 9.23 (4) 3.93	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) <0.001 ***	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) <0.001 ***
Pre – Late	(1) -6.49 (2) -4.03 (3) 6.20 (4) 0.09	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) 0.928	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) 1.000
Early – Intermediate	(1) 12.67 (2) 9.21 (3) -4.02 (4) -1.19	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) 0.235	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) 1.000
Early – Late	(1) 10.58 (2) 9.07 (3) -1.02 (4) 2.61	(1) <0.001 *** (2) <0.001 *** (3) 0.305 (4) 0.009 **	(1) <0.001 *** (2) <0.001 *** (3) <0.001 *** (4) 0.054
Intermediate – Late	(1) -1.98 (2) -0.11 (3) 2.88 (4) 3.67	(1) <0.05 * (2) 0.916 (3) 0.004 ** (4) <0.001 ***	(1) 0.283 (2) 1.000 (3) 0.024 * (4) <0.001 ***

Supplementary Table 4.5. Kruskal–Wallis non-parametric test for significant differences in factor score distributions between urban and rural settlements within each municipality (frontier stage). The test assesses whether the median scores differ significantly across groups. Statistically significant results are shown in bold and marked with an asterisk (*).

Municipality	**Factor (KW Test statistic, df = 1, *p-value*)**
Tefé (Pre frontier)	Forest Identity (1.06, *p = 0.303*); Forest Practicality (0.942, *p = 0.246*); Cattle Identity & Importance (1.70, *p = 0.193*); Cattle Utility (1.74, *p = 0.187*)
Lábrea (Early frontier)	Forest Identity (9.60, *p = 0.002***); Forest Practicality (1.69, *p = 0.193*); Cattle Identity & Importance (3.17, *p = 0.075*); **Cattle Utility (4.72, *p = 0.03*)***
São Félix do Xingu (Intermediate frontier)	Forest Identity (6.26, *p = 0.0123*)*; **Forest Practicality (9.76, *p = 0.002*)****; Cattle Identity & Importance (1.72, *p = 0.190*); Cattle Utility (2.22, *p = 0.136*)
Paragominas (Late frontier)	Forest Identity (1.64, *p = 0.200*); Forest Practicality (1.35, *p = 0.332*); Cattle Identity & Importance (0.994, *p = 0.319*); Cattle Utility (1.04, *p = 0.307*)

References

Acevedo, M.F. *et al.* (2008) 'Models of natural and human dynamics in forest landscapes: Cross-site and cross-cultural synthesis', *Geoforum*, 39(2), pp. 846–866. Available at: https://doi.org/10.1016/j.geoforum.2006.10.008.

Adams, C. *et al.* (2009) 'Amazon peasant societies in a changing environment: Political ecology, invisibility and modernity in the rainforest', *Amazon Peasant Societies in a Changing Environment: Political Ecology, Invisibility and Modernity in the Rainforest*, pp. 1–358. Available at: https://doi.org/10.1007/978-1-4020-9283-1.

Adams, R.T. (2015) 'An Emerging Alliance of Ranchers and Farmers in the Brazilian Amazon', *Journal of the Society for the Anthropology of Lowland South America*, 13(1), pp. 63–79. Available at: http://digitalcommons.trinity.edu/tipiti/vol13/iss1/4/.

Adger, W.N. *et al.* (2013) 'Cultural dimensions of climate change impacts and adaptation', *Nature Climate Change*, 3(2), pp. 112–117. Available at: https://doi.org/10.1038/nclimate1666.

Aitchson, J. (1986) *The statistical analysis of compositional data. Monographs on statistics and applied probability (Reprinted in 2003)*. Chapman and Hall London.

Aleixo, J. and APADRIT, A. dos P.A. da A. de D. do R.I. (2011) *Memorial da luta pela Reserva Extrativista do Ituxi em Lábrea-AM: Registro da mobilização social, organização comunitária e conquista da cidadania na Amazônia*. Available at: https://iieb.org.br/wp-content/uploads/2019/02/public_ieb_Resex_medio_purus.pdf.

Alencar, L., Parry, L. and Melo, F. (2025) 'Deforestation and human development in the Brazilian tropical dry forest', *Forest Policy and Economics*, 178(January), p. 103571. Available at: https://doi.org/10.1016/j.forpol.2025.103571.

Allen, M.R. *et al.* (2000) 'Quantifying the uncertainty in forecasts of anthropogenic climate change', *Nature*, 407(6804), pp. 617–620. Available at: https://doi.org/10.1038/35036559.

Anderson, C.B. *et al.* (2022) 'Chapter 2: Conceptualizing the diverse values of nature and their contributions to people.', *Methodological Assessment Report on the Diverse Values and Valuation of Nature of the Intergovernmental Science-Policy Platform on*

Biodiversity and Ecosystem Services, pp. 1–125. Available at: https://zenodo.org/record/7154713.

Angert, A.L. (2024) 'The space--for-time gambit fails a robust test', *PNAS*, 121(4), pp. 1–3.

Anselin, L. (1995) 'Local Indicators of Spatial Association—LISA', *Geographical Analysis*, 27(2), pp. 93–115. Available at: https://doi.org/10.1111/j.1538-4632.1995.tb00338.x.

Araujo, C., Combes, J.L. and Féres, J.G. (2019) 'Determinants of Amazon deforestation: The role of off-farm income', *Environment and Development Economics*, 24(2), pp. 138–156. Available at: https://doi.org/10.1017/S1355770X18000359.

de Area Leão Pereira, E.J. *et al.* (2020) 'Brazilian policy and agribusiness damage the Amazon rainforest', *Land Use Policy*, 92(January), p. 104491. Available at: https://doi.org/10.1016/j.landusepol.2020.104491.

Arias-Arévalo, P. *et al.* (2018) 'Widening the Evaluative Space for Ecosystem Services: A Taxonomy of Plural Values and Valuation Methods', *Environmental Values*, 27(1), pp. 29–53.

Arias-Arévalo, P. *et al.* (2023) 'The role of power in leveraging the diverse values of nature for transformative change', *Current Opinion in Environmental Sustainability*, 64, p. 101352. Available at: https://doi.org/10.1016/j.cosust.2023.101352.

Arima, E.Y. *et al.* (2014) 'Public policies can reduce tropical deforestation: Lessons and challenges from Brazil', *Land Use Policy*, 41(2014), pp. 465–473. Available at: https://doi.org/10.1016/j.landusepol.2014.06.026.

Arima, E.Y. *et al.* (2016) 'Explaining the fragmentation in the Brazilian Amazonian forest', *Journal of Land Use Science*, 11(3), pp. 257–277. Available at: https://doi.org/10.1080/1747423X.2015.1027797.

Arriagada, R. *et al.* (2018) 'Analysing the impacts of PES programmes beyond economic rationale: Perceptions of ecosystem services provision associated to the Mexican case', *Ecosystem Services*, 29, pp. 116–127. Available at: https://doi.org/10.1016/j.ecoser.2017.12.007.

De Assis Costa, F. *et al.* (2023) *Land Market And Illegalities: The Deep Roots Of*

Deforestation In The Amazon. Available at: https://doi.org/10.55161/SLBQ1069.

Assunção, J. *et al.* (2017) 'Property-level assessment of change in forest clearing patterns: The need for tailoring policy in the Amazon', *Land Use Policy*, 66(April), pp. 18–27. Available at: https://doi.org/10.1016/j.landusepol.2017.04.022.

Austin, K.G. *et al.* (2017) 'Trends in size of tropical deforestation events signal increasing dominance of industrial-scale drivers', *Environmental Research Letters*, 12(5). Available at: https://doi.org/10.1088/1748-9326/aa6a88.

Azevedo, A.A. *et al.* (2017) 'Limits of Brazil's Forest Code as a means to end illegal deforestation', *Proceedings of the National Academy of Sciences of the United States of America*, 114(29), pp. 7653–7658. Available at: https://doi.org/10.1073/pnas.1604768114.

Azzopardi, E. *et al.* (2023) 'What are heritage values? Integrating natural and cultural heritage into environmental valuation', *People and Nature*, 5(2), pp. 368–383. Available at: https://doi.org/10.1002/pan3.10386.

Barbosa, E.R.D.Q. (2021) '"Being the culture" and "playing the culture": Choro and the Brazilianness performed in Brussels', *Crossings*, 12(2), pp. 413–428. Available at: https://doi.org/10.1386/cjmc_00042_1.

Barlow, J. *et al.* (2018) 'The future of hyperdiverse tropical ecosystems', *Nature*, 559(7715), pp. 517–526. Available at: https://doi.org/10.1038/s41586-018-0301-1.

Barros, A. (2003) 'Paragominas: Projetos Demonstrativos, Prefeitura Em Ação E Controle Social Latente. In Municipios E Gestão Florestal Na Amazônia', *Toni F, Kaimowitz D (eds).* [Preprint], (A. S. Editores: Natal, Brazil).

Bashan, D., Colléony, A. and Shwartz, A. (2021) 'Urban versus rural? The effects of residential status on species identification skills and connection to nature', *People and Nature*, 3(2), pp. 347–358. Available at: https://doi.org/10.1002/pan3.10176.

Batavia, C. and Nelson, M.P. (2017) 'For goodness sake! What is intrinsic value and why should we care?', *Biological Conservation*, 209, pp. 366–376. Available at: https://doi.org/10.1016/j.biocon.2017.03.003.

Becker, J.C., Kraus, M.W. and Rheinschmidt-Same, M. (2017) 'Cultural Expressions of Social Class and Their Implications for Group-Related Beliefs and Behaviors', *Journal*

of Social Issues, 73(1), pp. 158–174. Available at: https://doi.org/10.1111/josi.12209.

Beery, T.H. and Wolf-Watz, D. (2014) 'Nature to place: Rethinking the environmental connectedness perspective', *Journal of Environmental Psychology*, 40, pp. 198–205. Available at: https://doi.org/10.1016/j.jenvp.2014.06.006.

Belik, L. and Belik, L. (2021) 'Radio as a Tool of Education and Resistance in Brazilian Communities during the Pandemic Radio as a Tool of Education and Resistance in Brazilian Communities during the Pandemic', *Design and Culture*, 13(1), pp. 79–90. Available at: https://doi.org/10.1080/17547075.2020.1871192.

Beling, A.E. *et al.* (2018) 'Discursive Synergies for a "Great Transformation" Towards Sustainability: Pragmatic Contributions to a Necessary Dialogue Between Human Development, Degrowth, and Buen Vivir', *Ecological Economics*, 144(March 2017), pp. 304–313. Available at: https://doi.org/10.1016/j.ecolecon.2017.08.025.

Bennett, A. (1999) 'Subcultures or neo-tribes? Rethinking the relationship between youth, style and musical taste', *Sociology*, 33(3), pp. 599–617. Available at: https://doi.org/10.1177/s0038038599000371.

Berry, J. (1992) 'Acculturation and adaptation in a new society', *International Migration* [Preprint].

Beza, B.B. *et al.* (2018) 'Place? Lugar? Sitio? Framing Place and Placemaking through Latin American Contexts', in *Urban Space: experiences and Reflections from the Global South*. Pontifica Universidad Javeriana Cali, p. 404.

Bland, J.M. and Altman, D.G. (2002) 'Validating scales and indexes', *British Medical Journal*, 324(7337), pp. 606–607.

Blois, J.L. *et al.* (2013) 'Space can substitute for time in predicting climate-change effects on biodiversity', *PNAS*, 110(23), pp. 9374–9379. Available at: https://doi.org/10.1073/pnas.1220228110.

Boas, F. (1932) 'The Aims of Anthropological Research', *Science*, 76(1983), pp. 605–613.

Boas, T.C. and Hidalgo, F.D. (2011) 'Controlling the Airwaves: Incumbency Advantage and Community Radio in Brazil', *American Journal of Political Science*, 55(4), pp. 868–884. Available at: https://doi.org/10.1111/j.1540-5907.2011.00532.x.

Börner, J. *et al.* (2017) 'The Effectiveness of Payments for Environmental Services', *World Development*, 96, pp. 359–374. Available at: https://doi.org/10.1016/j.worlddev.2017.03.020.

du Bray, M. V. *et al.* (2019) 'Does ecosystem services valuation reflect local cultural valuations? Comparative analysis of resident perspectives in four major urban river ecosystems', *Economic Anthropology*, 6(1), pp. 21–33. Available at: https://doi.org/10.1002/sea2.12128.

Breslow, N. (1996) 'Generalized Linear Models: Checking Assumptions and Strengthening Conclusions', *Journal of Statistics and Applications*, 8, pp. 23–41.

Brondizio, E.S. (2025) 'The entangled Indigenous, rural, and urban realities in Amazônia's governance', *Ambio*, 54(6), pp. 923–931. Available at: https://doi.org/10.1007/s13280-025-02183-z.

Brouwer, R.G. *et al.* (2021) 'Establishment success of Brazil nut trees in smallholder Amazon forest restoration depends on site conditions and management', *Forest Ecology and Management*, 498(February). Available at: https://doi.org/10.1016/j.foreco.2021.119575.

Browder, J.O. and Godfrey, B.J. (1997) *Rainforest Cities*. New York: Columbia University Press, New York.

Bush, M.B. *et al.* (2015) 'Anthropogenic influence on Amazonian forests in pre-history: An ecological perspective', *Journal of Biogeography*, 42(12), pp. 2277–2288. Available at: https://doi.org/10.1111/jbi.12638.

Cabana, G.S. (2011) 'The Problematic Relationship between Migration and Cultural Change', in *Rethinking Anthropological Perspectives on Migration*, pp. 16–31.

Caldas, M.M. *et al.* (2015) 'Opinion: Endogenizing culture in sustainability science research and policy', *Proceedings of the National Academy of Sciences of the United States of America*, 112(27), pp. 8157–8159. Available at: https://doi.org/10.1073/pnas.1510010112.

Cameron, C.A. and Miller, D.L. (2011) 'Robust Inference with Clustered Data', in *Handbook of Empirical Economics and Finance*. Routledge, p. 28. Available at: https://www.taylorfrancis.com/chapters/edit/10.1201/b10440-5/robust-inference-

clustered-data-colin-cameron-douglas-miller.

Carignano Torres, P. *et al.* (2016) 'Who Cares about Forests and Why? Individual Values Attributed to Forests in a Post-Frontier Region in Amazonia', *PLoS ONE*, 11(12), pp. 1–18. Available at: https://doi.org/10.1371/journal.pone.0167691.

Carignano Torres, P. *et al.* (2022) 'Wildmeat consumption and child health in Amazonia', *Scientific Reports*, 12(1), pp. 1–14. Available at: https://doi.org/10.1038/s41598-022-09260-3.

Carignano Torres, P., Morsello, C. and Parry, L. (2022) 'Rural-urban mobility influences wildmeat access and consumption in the Brazilian Amazon', *Oryx*, 56(6), pp. 864–876. Available at: https://doi.org/10.1017/S0030605321001575.

Carmenta, R. *et al.* (2020) 'Characterizing and Evaluating Integrated Landscape Initiatives', *One Earth*, 2(2), pp. 174–187. Available at: https://doi.org/10.1016/j.oneear.2020.01.009.

Carmenta, R., Barlow, J., *et al.* (2023) 'Connected Conservation: Rethinking conservation for a telecoupled world', *Biological Conservation*, 282.

Carmenta, R., Zaehringer, J.G., *et al.* (2023) 'Exploring the relationship between plural values of nature, human well-being, and conservation and development intervention: Why it matters and how to do it?', *People and Nature*, 5(6), pp. 1720–1738. Available at: https://doi.org/10.1002/pan3.10562.

Carr, D. (2009) 'Population and deforestation: Why rural migration matters', *Progress in Human Geography*, 33(3), pp. 355–378. Available at: https://doi.org/10.1177/0309132508096031.

Carreira, I., Costa, F. and Pessoa, J.P. (2024) 'The deforestation effects of trade and agricultural productivity in Brazil', *Journal of Development Economics*, 167(November 2023), p. 103217. Available at: https://doi.org/10.1016/j.jdeveco.2023.103217.

Carrero, G.C. *et al.* (2020) 'Deforestation Trajectories on a Development Frontier in the Brazilian Amazon: 35 Years of Settlement Colonization, Policy and Economic Shifts, and Land Accumulation', *Environmental Management*, 66(6), pp. 966–984. Available at: https://doi.org/10.1007/s00267-020-01354-w.

Carrero, G.C. *et al.* (2022) 'Land grabbing in the Brazilian Amazon: Stealing public

land with government approval', *Land Use Policy*, 120(January), p. 106133. Available at: https://doi.org/10.1016/j.landusepol.2022.106133.

Castello, L. and Macedo, M.N. (2016) 'Large-scale degradation of Amazonian freshwater ecosystems', *Global Change Biology*, 22(3), pp. 990–1007. Available at: https://doi.org/10.1111/gcb.13173.

Chan, K.M., Gould, R.K. and Pascual, U. (2018) 'Relational values: what are they, and what's the fuss about?', *Current Opinion in Environmental Sustainability*, 35, pp. A1–A7. Available at: https://doi.org/10.1016/j.cosust.2018.11.003.

Chan, K.M.A. *et al.* (2016) 'Why protect nature? Rethinking values and the environment', *Proceedings of the National Academy of Sciences of the United States of America*, 113(6), pp. 1462–1465. Available at: https://doi.org/10.1073/pnas.1525002113.

Chan, K.M.A. *et al.* (2017) 'Payments for Ecosystem Services: Rife With Problems and Potential—For Transformation Towards Sustainability', *Ecological Economics*, 140, pp. 110–122. Available at: https://doi.org/10.1016/j.ecolecon.2017.04.029.

Chan, K.M.A. *et al.* (2020) 'Levers and leverage points for pathways to sustainability', *People and Nature*, 2(3), pp. 693–717. Available at: https://doi.org/10.1002/pan3.10124.

Chan, K.M.A. *et al.* (2025) 'The multiple values of nature show the lack of a coherent theory of value—In any context', *People and Nature*, 7(6), pp. 1272–1285. Available at: https://doi.org/10.1002/pan3.70039.

Chaves, W.A. *et al.* (2024) 'Urbanization and food transition in the Brazilian Amazon: From wild to domesticated meat', *People and Nature*, (September), pp. 1–14. Available at: https://doi.org/10.1002/pan3.10746.

Cleary, D. (2001) 'Towards an environmental history of the Amazon: From prehistory to the nineteenth century', *Latin American Research Review*, 36(2), pp. 65–96. Available at: https://doi.org/10.1017/s0023879100018999.

Cohn, A.S. *et al.* (2014) 'Cattle ranching intensification in Brazil can reduce global greenhouse gas emissions by sparing land from deforestation', *Proceedings of the National Academy of Sciences of the United States of America*, 111(20), pp. 7236–7241.

Available at: https://doi.org/10.1073/pnas.1307163111.

Corbera, E. and Schroeder, H. (2011) 'Governing and implementing REDD+', *Environmental Science and Policy*, 14(2), pp. 89–99. Available at: https://doi.org/10.1016/j.envsci.2010.11.002.

Costa, F. de A. *et al.* (2024) 'Complex, diverse, and changing agribusiness and livelihood systems in the Amazon', *Acta Amazonica*, 54(Special 1), pp. 1–48. Available at: https://doi.org/10.55161/cgap7652.

Costa, S.M. and Brondízio, E.S. (2009) 'Dependência inter-urbana entre as Cidades Amazônicas: Crescimento Urbano, Deficiências em Infra-estrutura e Redes Sociais', *Redes*, 14(3), pp. 211–234.

Costanza, R. *et al.* (1997) 'The value of the world's ecosystem services and natural capital. LK - https://royalroads.on.worldcat.org/oclc/4592801201', *Nature TA - TT* -, 387(6630), pp. 253–260. Available at: https://www-nature-com.ezproxy.royalroads.ca/articles/387253a0.pdf.

Costanza, R. *et al.* (2017) 'Twenty years of ecosystem services: How far have we come and how far do we still need to go?', *Ecosystem Services*, 28, pp. 1–16. Available at: https://doi.org/10.1016/j.ecoser.2017.09.008.

Costanza, R. and Daly, H.E. (1992) 'Natural Capital and Sustainable Development', *Source: Conservation Biology*, 6(1), pp. 37–46. Available at: http://www.jstor.org/stable/2385849%5Cnhttp://www.jstor.org/page/info/about/policies/terms.jsp.

Cowling, P. (2005) 'An Earthy Enigma: The Role of Localism in the Political, Cultural and Economic Dimensions of Media Ownership Regulation An Earthy Enigma: The Role of Localism in the Political, Cultural and Economic Dimensions of Media Ownership Regulation', *UC Law SF Communications and Entertainment Journal*, 27(2), pp. 259–353.

Cresswell, T. (2015) *Place: An Introduction*. 2nd edn. Wiley.

Damgaard, C. (2019) 'A Critique of the Space-for-Time Substitution Practice in Community Ecology', *Trends in Ecology and Evolution*, 34(5), pp. 416–421. Available at: https://doi.org/10.1016/j.tree.2019.01.013.

Deininger, K. and Minten, B. (2002) ‘Determinants of deforestation and the economics of protection: An application to Mexico’, *American Journal of Agricultural Economics*, 84(4), pp. 943–960. Available at: https://doi.org/10.1111/1467-8276.00359.

Demmer, J. and Overman, H. (2001) ‘Indigenous people conserving the rain forest? The effect of wealth and markets on the economic behaviour of Tawahka Amerindians in Honduras’, *Tropenbos International*, 1(1383–6811), p. 399. Available at: https://www.cabdirect.org/cabdirect/abstract/19501100562.

Dent, A.S. (2009) *River of Tears: Country Music, Memory and Modernity in Brazil*. Duke University Press. Available at: https://www.dukeupress.edu/river-of-tears.

DiStefano, C. and Morgan, G.B. (2014) ‘A Comparison of Diagonal Weighted Least Squares Robust Estimation Techniques for Ordinal Data’, *Structural Equation Modeling*, 21(3), pp. 425–438. Available at: https://doi.org/10.1080/10705511.2014.915373.

Dlamini, S. *et al.* (2021) ‘Spatio-temporal patterns and changes in environmental attitudes and place attachment in Gauteng, South Africa’, *Geo-Spatial Information Science*, 24(4), pp. 666–677. Available at: https://doi.org/10.1080/10095020.2021.1976599.

Dodd, L.M.M. (2020) ‘Aspiring to a Good Life: Rural–Urban Mobility and Young People’s Desires in the Brazilian Amazon’, *Journal of Latin American and Caribbean Anthropology*, 25(2), pp. 283–300. Available at: https://doi.org/10.1111/jlca.12478.

Dunn, O.J. (1964) ‘Multiple Comparisons Using Rank Sums’, *Technometrics*, 6(3), pp. 241–252. Available at: https://doi.org/doi/abs/10.1080/00401706.1964.10490181.

EJAtlas (2025) *EJAtlas - Global Atlas of Environmental Justice*. Available at: https://ejatlas.org/ (Accessed: 31 May 2025).

Evans, M.E.K. *et al.* (2025) ‘Reconsidering space-for-time substitution in climate change ecology’, *Nature Climate Change*, 15(August), pp. 809–812. Available at: https://doi.org/10.1038/s41558-025-02392-0.

Fanon, F. (1963) *Wretched of the Earth*. Grove Press.

Fearnside, P. (2018) *Why Brazil’s New President Poses an Unprecedented Threat to the Amazon*, *Yale Environment 360*.

Fearnside, P.M. (2005) ‘Deforestation in Brazilian Amazonia: History, rates, and consequences’, *Conservation Biology*, 19(3), pp. 680–688. Available at: https://doi.org/10.1111/j.1523-1739.2005.00697.x.

Fearnside, P.M. (2008) ‘The roles and movements of actors in the deforestation of Brazilian Amazonia’, *Ecology and Society*, 13(1). Available at: https://doi.org/10.5751/ES-02451-130123.

Fearnside, P.M., Figueiredo, A.M.R. and Bonjour, S.C.M. (2013) ‘Amazonian forest loss and the long reach of China’s influence’, *Environment, Development and Sustainability*, 15(2), pp. 325–338. Available at: https://doi.org/10.1007/s10668-012-9412-2.

Fearnside, P.M. and Filho, W.L. (2025) ‘COP 30: Brazilian policies must change’, *Science*, 387(6740), p. 1237. Available at: https://doi.org/10.1126/science.adu9113.

Fernández-Giménez, M.E. *et al.* (2017) ‘Exploring linked ecological and cultural tipping points in Mongolia’, *Anthropocene*, 17, pp. 46–69. Available at: https://doi.org/10.1016/j.ancene.2017.01.003.

Filho, L. *et al.* (2021) ‘The Economy of Cattle Ranching in the Amazon: Land Grabbing or Pushing the Agricultural Frontier?’, 99(October), pp. 1–5.

Fingerhut, J. *et al.* (2021) ‘The Aesthetic Self. The Importance of Aesthetic Taste in Music and Art for Our Perceived Identity’, *Frontiers in Psychology*, 11(March), pp. 1–18. Available at: https://doi.org/10.3389/fpsyg.2020.577703.

Fletcher, R. *et al.* (2016) ‘Questioning REDD+ and the future of market-based conservation’, *Conservation Biology*, 30(3), pp. 673–675. Available at: https://doi.org/10.1111/cobi.12680.

Flores, B.M. *et al.* (2024) ‘Critical transitions in the Amazon forest system’, *Nature*, 626(7999), pp. 555–564. Available at: https://doi.org/10.1038/s41586-023-06970-0.

Fraser, J.A. *et al.* (2018) ‘Amazonian peasant livelihood differentiation as mutuality-market dialectics’, *Journal of Peasant Studies*, 45(7), pp. 1382–1409. Available at: https://doi.org/10.1080/03066150.2017.1296833.

Fraser, J.A. (2018) ‘Amazonian struggles for recognition’, *Transactions of the Institute of British Geographers*, 43(4), pp. 718–732. Available at:

https://doi.org/10.1111/tran.12254.

Freitas, M.A.B. *et al.* (2015) 'Floristic impoverishment of Amazonian floodplain forests managed for açaí fruit production', *Forest Ecology and Management*, 351, pp. 20–27. Available at: https://doi.org/10.1016/j.foreco.2015.05.008.

Garnelo, L., Fearnside, P.M. and Ferrante, L. (2023) 'Amazon: between devastation, violence, and threads of hope', *Cadernos de Saude Publica*, 39(12). Available at: https://doi.org/10.1590/0102-311XEN152723.

Garrett, R. *et al.* (2024) 'Transformative changes are needed to support socio-bioeconomies for people and ecosystems in the Amazon', *Nature Ecology and Evolution*, 8(October), pp. 1815–1825. Available at: https://doi.org/10.1038/s41559-024-02467-9.

Garrett, R.D. *et al.* (2017) 'Explaining the persistence of low income and environmentally degrading land uses in the Brazilian Amazon', *Ecology and Society*, 22(3). Available at: https://doi.org/10.5751/ES-09364-220327.

Garrett, R.D. *et al.* (2018) 'Intensification in agriculture-forest frontiers: Land use responses to development and conservation policies in Brazil', *Global Environmental Change*, 53(October 2017), pp. 233–243. Available at: https://doi.org/10.1016/j.gloenvcha.2018.09.011.

Gauthier, T.D. (2001) 'Detecting trends using spearman's rank correlation coefficient', *Environmental Forensics*, 2(4), pp. 359–362. Available at: https://doi.org/10.1080/713848278.

Geertz, C. (1973) *The Interpretation of Cultures*. Basic Books.

Geertz, C. (1995) 'The World in Pieces: Culture and Politics at the End of the Century', in *Available light: anthropological reflections on philosophical topics*. Princeton University press, pp. 218–263.

Ghosh, P. *et al.* (2023) 'A Study on Music Genre Classification using Machine Learning', *International Journal of Business and Social Science*, 1(4), pp. 257–268. Available at: http://www.ijbssnet.com/journals/Vol_4_No_1_January_2013/26.pdf.

Gibbs, H.K. *et al.* (2015) 'Brazil's Soy Moratorium', *Science*, 347(6220), pp. 377–378. Available at: https://doi.org/10.1126/science.aaa0181.

Gibbs, H.K. *et al.* (2016) 'Did Ranchers and Slaughterhouses Respond to Zero-Deforestation Agreements in the Brazilian Amazon?', *Conservation Letters*, 9(1), pp. 32–42. Available at: https://doi.org/10.1111/conl.12175.

Godar, J. *et al.* (2014) 'Actor-specific contributions to the deforestation slowdown in the Brazilian Amazon', *Proceedings of the National Academy of Sciences of the United States of America*, 111(43), pp. 15591–15596. Available at: https://doi.org/10.1073/pnas.1322825111.

Godoi Barroso, B. and Forattini, F.M. (2020) 'Brazilian 'Sertaneja'/Countryside Music and the Formation and Expression of Brazilian Rural and Migrant Culture', *SSRN Electronic Journal* [Preprint]. Available at: https://doi.org/10.2139/ssrn.3737024.

Goebel, L.G.A. *et al.* (2025) 'The impact of Amazon deforestation is magnified by changing the configuration of forest cover', *Environmental Conservation* [Preprint]. Available at: https://doi.org/10.1017/S0376892925000086.

Gomes, C.V.A. (2009) *Twenty years after Chico Mendes: Extractive reserves' expansion, cattle adoption and evolving self-definition among rubber tappers in the Brazilian Amazon*.

Gomes, C.V.A. *et al.* (2018) 'Extractive Reserves in the Brazilian Amazon thirty years after Chico Mendes: Social movement achievements, territorial expansion and continuing struggles', *Desenvolvimento e Meio Ambiente*, 48, pp. 74–98. Available at: https://doi.org/10.5380/dma.v48i0.58830.

Gomes, C.V.A. and Schmink, M. (2008) 'Planejando Futuros Sustentáveis com Pequenos Produtores: Programa Proambiente Pólo Alto Acre', *O Manejo da Paisagem e a Paisagem do Manejo*, 5(1), pp. 121–156. Available at: https://revistas.ufrj.br/index.php/rce/article/download/1659/1508%0Ahttp://hipatiapress.com/hpjournals/index.php/qre/article/view/1348%5Cnhttp://www.tandfonline.com/doi/abs/10.1080/09500799708666915%5Cnhttps://mckinseyonsociety.com/downloads/reports/Educa.

Gomes, C.V.A., Vadjunec, J.M. and Perz, S.G. (2012) 'Rubber tapper identities: Political-economic dynamics, livelihood shifts, and environmental implications in a changing Amazon', *Geoforum*, 43(2), pp. 260–271. Available at: https://doi.org/10.1016/J.GEOFORUM.2011.09.005.

Gonçalves-Souza, D. *et al.* (2021) 'The role of protected areas in maintaining natural vegetation in Brazil', *Science Advances*, 7(38). Available at: https://doi.org/10.1126/sciadv.abh2932.

Gould, R.K., Jimenez Naranjo, Y. and Balvanera, P. (2025) 'Relationality is not WEIRD: the importance of relational thinking in the majority of the planet's societies', *Ecosystems and People*, 21(1). Available at: https://doi.org/10.1080/26395916.2024.2427810.

Gould, R.K., Martinez, D.E. and Hoelting, K.R. (2023) 'Exploring Indigenous relationality to inform the relational turn in sustainability science', *Ecosystems and People*, 19(1). Available at: https://doi.org/10.1080/26395916.2023.2229452.

Gould, R.K., Morse, J.W. and Adams, A.B. (2019) 'Cultural ecosystem services and decision-making: How researchers describe the applications of their work', *People and Nature*, 1(4), pp. 457–475. Available at: https://doi.org/10.1002/pan3.10044.

Graham, S. *et al.* (2023) 'An interdisciplinary framework for navigating social–climatic tipping points', *People and Nature*, 5(5), pp. 1445–1456. Available at: https://doi.org/10.1002/pan3.10516.

Gray, C.L. *et al.* (2008) 'Indigenous land use in the Ecuadorian Amazon: A cross-cultural and multilevel analysis', *Human Ecology*, 36(1), pp. 97–109. Available at: https://doi.org/10.1007/s10745-007-9141-6.

Guanziroli, C., Buainain, A. and Sabbato, A. (2013) 'Family farming in Brazil: Evolution between the 1996 and 2006 agricultural censuses', *Journal of Peasant Studies*, 40(5), pp. 817–843. Available at: https://doi.org/10.1080/03066150.2013.857179.

Guedes, G.R., Costa, S.M. and Brondízio, E.S. (2009) 'Revisiting the hierarchy of urban areas in the Brazilian Amazon: a multilevel approach', *Population and Environment*, 30(4–5), pp. 159–192. Available at: https://doi.org/10.1007/s11111-009-0083-3.Revisiting.

Guyot, S. (2011) 'The Eco-frontier paradigm: Rethinking the links between space, nature and politics', *Geopolitics*, 16(3), pp. 675–706. Available at: https://doi.org/10.1080/14650045.2010.538878.

Haddad, E.A. *et al.* (2024) 'Economic drivers of deforestation in the Brazilian Legal Amazon', *Nature Sustainability*, 7(9), pp. 1141–1148. Available at: https://doi.org/10.1038/s41893-024-01387-7.

Hanaček, K. and Rodríguez-Labajos, B. (2018) 'Impacts of land-use and management changes on cultural agroecosystem services and environmental conflicts—A global review', *Global Environmental Change*, 50(December 2017), pp. 41–59. Available at: https://doi.org/10.1016/j.gloenvcha.2018.02.016.

Hauke, J. and Kossowski, T. (2011) 'Comparison of values of pearson's and spearman's correlation coefficients on the same sets of data', *Quaestiones Geographicae*, 30(2), pp. 87–93. Available at: https://doi.org/10.2478/v10117-011-0021-1.

Hays, S. (1994) 'Structure and Agency and the Sticky Problem of Culture', *American Sociological Association*, 12(1), pp. 57–72. Available at: http://www.jstor.org/stable/202035.

Hecht, S. (2010) 'The new rurality: Globalization, peasants and the paradoxes of landscapes', *Land Use Policy*, 27(2), pp. 161–169. Available at: https://doi.org/10.1016/j.landusepol.2009.08.010.

Hecht, S. (2015) 'Smallholders, forest management and rural development in the Amazon', *The Journal of Peasant Studies*, 42(1), pp. 233–236. Available at: https://doi.org/10.1080/03066150.2014.978139.

Hecht, S. *et al.* (2024) 'Amazon in Motion: Changing politics, development strategies, peoples, landscapes, and livelihoods', *Acta Amazonica*, 54(Special 1), pp. 1–50. Available at: https://doi.org/10.55161/nhrc6427.

Hecht, S.B. (1993) 'The Logic of Livestock and Deforestation in Amazonia', *BioScience*, 43(10), pp. 687–695. Available at: https://doi.org/10.2307/1312340.

Hecht, S.B. (2007) 'Factories, forests, fields and family: Gender and neoliberalism in extractive reserves', *Journal of Agrarian Change*, 7(3), pp. 316–347. Available at: https://doi.org/10.1111/j.1471-0366.2007.00148.x.

Hecht, S.B. and Cockburn, A. (1989) *The Fate of the Forest: Developers, Destroyers, and Defenders of the Amazon*. University of Chicago Press.

Heckenberger, M.J. *et al.* (2007) 'The legacy of cultural landscapes in the Brazilian

Amazon: Implications for biodiversity', *Philosophical Transactions of the Royal Society B: Biological Sciences*, 362(1478), pp. 197–208. Available at: https://doi.org/10.1098/rstb.2006.1979.

Heip, C.H.R., Herman, P.M.J. and Soetaert, K. (1998) 'Indices of diversity and evenness', *Oceanis*, 24(2459), pp. 61–87.

Herrera, D., Pfaff, A. and Robalino, J. (2019) 'Impacts of protected areas vary with the level of government: Comparing avoided deforestation across agencies in the Brazilian Amazon', *Proceedings of the National Academy of Sciences of the United States of America*, 116(30), pp. 14916–14925. Available at: https://doi.org/10.1073/pnas.1802877116.

Himes, A. *et al.* (2024) 'Why nature matters: A systematic review of intrinsic, instrumental, and relational values', *BioScience*, 74(1), pp. 25–43. Available at: https://doi.org/10.1093/biosci/biad109.

Himes, A. *et al.* (2025) 'Horizontal portability: A proposal for representing place-based relational values in research and policy', *People and Nature*, 7(4), pp. 752–764. Available at: https://doi.org/10.1002/pan3.70016.

Himes, A. and Muraca, B. (2018) 'Relational values: the key to pluralistic valuation of ecosystem services', *Current Opinion in Environmental Sustainability*, 35, pp. 1–7. Available at: https://doi.org/10.1016/j.cosust.2018.09.005.

Hodel, L., le Polain de Waroux, Y. and Garrett, R.D. (2024) 'Characterizing culture's influence in land systems', *Nature Sustainability* [Preprint]. Available at: https://doi.org/10.1038/s41893-024-01381-z.

Hodel, L.J. (2023) 'Cattle , Culture , and Feminist Ecologies in the Brazilian Amazon : Advances in Theoretical and Al-Driven Land System Science Cattle , Culture , and Feminist Ecologies in the Brazilian', (29869).

Hoelle, J. (2011) 'Convergence on Cattle: Political Ecology, Social Group Perceptions, and Socioeconomic Relationships in Acre, Brazil', *Culture, Agriculture, Food and Environment*, 33(2), pp. 95–106. Available at: https://doi.org/10.1111/j.2153-9561.2011.01053.x.

Hoelle, J. (2014) 'Cattle culture in the Brazilian Amazon', *Human Organization*, 73(4),

pp. 363–374. Available at: https://doi.org/10.17730/humo.73.4.u61u675428341165.

Hoelle, J. (2015) *Rainforest Cowboys: The Rise of Ranching and Cattle Culture in Western Amazonia*. Latin Amer. Texas: University of Texas Press. Available at: https://utpress.utexas.edu/books/hoelle-rainforest-cowboys.

Hoelle, J. (2017) 'Jungle beef: Consumption, production and destruction, and the development process in the Brazilian Amazon', *Journal of Political Ecology*, 24(1), pp. 743–762. Available at: https://doi.org/10.2458/v24i1.20964.

Hoelle, J. (2018) 'Quantifying cultural values associated with deforestation in the Brazilian Amazon', *Journal of Land Use Science*, 13(1–2), pp. 166–181. Available at: https://doi.org/10.1080/1747423X.2018.1475516.

Hoelle, J., Gould, R.K. and Tauro, A. (2022) 'Beyond "desirable" values: Expanding relational values research to reflect the diversity of human–nature relationships', *People and Nature*, (November), pp. 1–12. Available at: https://doi.org/10.1002/pan3.10316.

Horcea-Milcu, A.I. *et al.* (2023) 'Modes of mobilizing values for sustainability transformation', *Current Opinion in Environmental Sustainability*, 64(July), p. 101357. Available at: https://doi.org/10.1016/j.cosust.2023.101357.

Hordge-Freeman, E. (2015) 'Out of Bounds?: Negotiating Researcher Positionality in Brazil', in *Bridging Scholarship and Activism: Reflections from the Frontlines of Collaborative Research*. eds. Bernd Reiter and Ulrich Oslender, Michigan State University Press, pp. 123–133.

Hu, L.T. and Bentler, P.M. (1999) 'Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives', *Structural Equation Modeling*, 6(1), pp. 1–55. Available at: https://doi.org/10.1080/10705519909540118.

Ioris, A.A.R. (2018) 'Place-making at the frontier of Brazilian agribusiness', *GeoJournal*, 83(1), pp. 61–72. Available at: https://doi.org/10.1007/s10708-016-9754-7.

IPBES (2024) *Summary for Policymakers of the Thematic Assessment Report on the Underlying Causes of Biodiversity Loss and the Determinants of Transformative Change and Options for Achieving the 2050 Vision for Biodiversity of the Intergovernmental Science-Policy Platf*, *IPBES secretariat*. Available at: https://doi.org/10.5281/zenodo.11382230.

Ishihara, H. (2018) 'Relational values from a cultural valuation perspective: how can sociology contribute to the evaluation of ecosystem services?', *Current Opinion in Environmental Sustainability*, 35, pp. 61–68. Available at: https://doi.org/10.1016/j.cosust.2018.10.016.

Iverson Nassauer, J. (1995) 'Culture and changing landscape structure', *Landscape Ecology*, 10(4), pp. 229–237. Available at: https://doi.org/10.1007/BF00129257.

Ives, C.D. *et al.* (2024) 'The role of religion in shaping the values of nature', *Ecology and Society*, 29(2). Available at: https://doi.org/10.5751/ES-15004-290210.

Ives, C.D. and Fischer, J. (2017) 'The self-sabotage of conservation: reply to Manfredo et al.', *Conservation Biology*, 31(6), pp. 1483–1485.

Ives, C.D., Freeth, R. and Fischer, J. (2020) 'Inside-out sustainability: The neglect of inner worlds', *Ambio*, 49(1), pp. 208–217. Available at: https://doi.org/10.1007/s13280-019-01187-w.

Ives, C.D. and Kendal, D. (2013) 'Values and attitudes of the urban public towards peri-urban agricultural land', *Land Use Policy*, 34, pp. 80–90. Available at: https://doi.org/10.1016/j.landusepol.2013.02.003.

Jacob, M.M. *et al.* (2021) 'Indigenous cultural values counter the damages of white settler colonialism', *Environmental Sociology*, 7(2), pp. 134–146. Available at: https://doi.org/10.1080/23251042.2020.1841370.

Jacobs, S. *et al.* (2020) 'Use your power for good: Plural valuation of nature – the Oaxaca statement', *Global Sustainability*, 3, pp. 1–7. Available at: https://doi.org/10.1017/sus.2020.2.

Johnson, A. *et al.* (2022) 'More than an academic exercise: Structuring international partnerships to build research and professional capacity for conservation impact', *Conservation Science and Practice*, 4(5), pp. 1–8. Available at: https://doi.org/10.1111/csp2.539.

Johnson, E.A. and Miyanishi, K. (2008) 'Testing the assumptions of chronosequences in succession', *Ecology Letters*, 11, pp. 419–431. Available at: https://doi.org/10.1111/j.1461-0248.2008.01173.x.

Kaimowitzavid, D. *et al.* (2004) 'Hamburger connection fuels Amazon desctruction :

cattle ranching and deforestation in Brazil's Amazon', *Statistics*, pp. 1–10.

Kempton, W. and Holland, D.C. (2003) *Identity and sustained environmental practice in S. Clayton and S. Opotow, (eds.)*, *Identity and the Natural Environment: The Psychological Significance of Nature*. MIT Press (Cambridge, Massachussets). Available at: https://doi.org/10.7551/mitpress/3644.001.0001.

Kendal, D. and Raymond, C.M. (2019) 'Understanding pathways to shifting people's values over time in the context of social–ecological systems', *Sustainability Science*, 14(5), pp. 1333–1342. Available at: https://doi.org/10.1007/S11625-018-0648-0.

Kenter, J.O. (2016) 'Editorial: Shared, plural and cultural values', *Ecosystem Services*, 21(October), pp. 175–183. Available at: https://doi.org/10.1016/j.ecoser.2016.10.010.

Kenter, J.O. *et al.* (2025) 'Ten principles for transforming economics in a time of global crises', *Nature Sustainability*, 8(7), pp. 837–847. Available at: https://doi.org/10.1038/s41893-025-01562-4.

Killeen, T. (2025) *Chapter 6: Culture and Demographics Define the Present*, *A Perfect Storm in the Amazon Wilderness: Volume 2*. Available at: https://doi.org/10.3197/9781912186228.ch07.

Kim, H.S. and Sherman, D.K. (2007) '"Express yourself": Culture and the effect of self-expression on choice', *Journal of Personality and Social Psychology*, 92(1), pp. 1–11. Available at: https://doi.org/10.1037/0022-3514.92.1.1.

Klain, S.C. *et al.* (2017) 'Realtional values resonate broadly and differently than instrinsic or instrumental values or the NEP', *PLoS ONE*, 12(8), pp. 1–21. Available at: https://doi.org/10.1016/j.cosust.2018.11.003.

Kleespies, M.W. and Dierkes, P.W. (2020) 'Exploring the Construct of Relational Values: An Empirical Approach', *Frontiers in Psychology*, 11(March), pp. 1–14. Available at: https://doi.org/10.3389/fpsyg.2020.00209.

Kluckhohn, C. (1951) 'Values and Value-Orientations in the Theory of Action: An Exploration in Definition and Classification', in *Toward a General Theory of Action*. Harvard University Press, pp. 388–433. Available at: https://doi.org/doi.org/10.4159.

Koehrsen, J. and Ives, C.D. (2025) 'The multiple roles of religious actors in advancing a sustainable future', *Ambio* [Preprint]. Available at: https://doi.org/10.1007/s13280-025-

02166-0.

Kohler, F. *et al.* (2011) 'Globalization in the Brazilian Amazon Region: Conflicting Answers from "Quilombo" Communities', *New Knowledge in a New Era of Globalization* [Preprint]. Available at: https://doi.org/10.5772/25192.

Kolinjivadi, V., Van Hecken, G. and Merlet, P. (2023) 'Fifteen years of research on payments for ecosystem services (PES): Piercing the bubble of success as defined by a Northern-driven agenda', *Global Environmental Change*, 83(August), p. 102758. Available at: https://doi.org/10.1016/j.gloenvcha.2023.102758.

Kottak, C.P. (1999) 'The New Ecological Anthropology', *American Anthropologist*, 101(1), pp. 23–35. Available at: https://doi.org/10.1525/aa.1999.101.1.23.

Kreitzman, M. *et al.* (2022) 'Local knowledge and relational values of Midwestern woody perennial polyculture farmers can inform tree- - crop policies', *People and Nature*, 4, pp. 180–200. Available at: https://doi.org/10.1002/pan3.10275.

Kröger, M. (2020) 'Deforestation, cattle capitalism and neodevelopmentalism in the Chico Mendes Extractive Reserve, Brazil', *Journal of Peasant Studies*, 47(3), pp. 464–482. Available at: https://doi.org/10.1080/03066150.2019.1604510.

Kuper, A. (2000) *Culture*. Harvard University Press. Available at: https://www.hup.harvard.edu/catalog.php?isbn=9780674004177.

Lambin, E.F., Geist, H.J. and Lepers, E. (2003) 'Dynamics of land-use and land-cover change in tropical regions', *Annual Review of Environment and Resources*, 28, pp. 205–241. Available at: https://doi.org/10.1146/annurev.energy.28.050302.105459.

Lamen, D. (2013) 'Claiming Caribbeanness in the Brazilian Amazon: Lambada, Critical Cosmopolitanism, and the Creation of an Alternative Amazon', *Latin American Music Review*, 34(2), pp. 131–161. Available at: https://doi.org/10.7560/LAMR34201.

Lamy, P. and Levin, J. (1985) 'Punk and Middle-Class Values: A Content Analysis', *Youth and Society*, 17(2), pp. 157–170.

Lathuillière, M.J. *et al.* (2019) 'Cattle production in Southern Amazonia: Implications for land and water management', *Environmental Research Letters*, 14(11). Available at: https://doi.org/10.1088/1748-9326/ab30a7.

Lawrence, T.J. *et al.* (2019) 'Rethinking Landscape Conservation: Linking Globalized Agriculture to Changes to Indigenous Community-Managed Landscapes', *Tropical Conservation Science*, 12. Available at: https://doi.org/10.1177/1940082919889503.

Lele, S. (2023) 'Value articulation in environmental appraisal: which values, whose values, and how valued?', *Current Opinion in Environmental Sustainability*, 63, p. 101294. Available at: https://doi.org/10.1016/j.cosust.2023.101294.

Lengieza, M.L. and Aviste, R. (2025) 'Relationships between people and nature: Nature connectedness and relational environmental values', *Current Opinion in Psychology*, 62, p. 101984. Available at: https://doi.org/10.1016/j.copsyc.2024.101984.

Lengieza, M.L., Aviste, R. and Richardson, M. (2023) 'The Human–Nature Relationship as a Tangible Target for Pro-Environmental Behaviour—Guidance from Interpersonal Relationships', *Sustainability (Switzerland)*, 15(16). Available at: https://doi.org/10.3390/su151612175.

Leu, L. (2006) 'Music and National Culture : Pop Music and Resistance in Brazil', *Cultural Studies*, 0(1), pp. 36–44. Available at: https://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1024&context=p.

Levers, C. *et al.* (2021) 'Agricultural expansion and the ecological marginalization of forest-dependent people', *Proceedings of the National Academy of Sciences of the United States of America*, 118(44), pp. 1–9. Available at: https://doi.org/10.1073/pnas.2100436118.

Levis, C. *et al.* (2018) 'How people domesticated Amazonian forests', *Frontiers in Ecology and Evolution*, 5(JAN). Available at: https://doi.org/10.3389/fevo.2017.00171.

Levy, S.A. *et al.* (2023) 'Deforestation in the Brazilian Amazon could be halved by scaling up the implementation of zero-deforestation cattle commitments', *Global Environmental Change*, 80(April), p. 102671. Available at: https://doi.org/10.1016/j.gloenvcha.2023.102671.

Lima, M.E. (2019) 'The Great Hope: Agrarian Policy in the Sertanejo song repertoire during the military dictatorship (1964 - 1985)', *Sociologia e Antropologia*, 9(1), pp. 212–234.

Little, P.E. (2001) *Amazonia: Territorial Struggles on Perennial Frontiers*. The John

Hopkins University Press.

Liu, L. and Wu, J. (2025) ‘Geography and Sustainability Space cannot substitute for time in the study of the ecosystem services-human wellbeing relationship’, *Geography and Sustainability*, 6(2), p. 100221. Available at: https://doi.org/10.1016/j.geosus.2024.08.002.

Lliso, B. *et al.* (2022) ‘Motivational crowding effects in payments for ecosystem services : Exploring the role of instrumental and relational values’, *People and Nature*, 4, pp. 312–329. Available at: https://doi.org/10.1002/pan3.10280.

Lovell, R.S.L. *et al.* (2023) ‘Space-for-time substitutions in climate change ecology and evolution’, *Biological Reviews*, 98, pp. 2243–2270. Available at: https://doi.org/10.1111/brv.13004.

Mace, G.M. (2014) ‘Whose conservation? Changes in the perception and goals of nature conservation require a solid scientific basis’, *Science*, 245(6204), pp. 1558–1560.

Maffi, L. (2018) ‘Biocultural Diversity’, *The International Encyclopedia of Anthropology* [Preprint]. Available at: https://doi.org/doi.org/10.1002/9781118924396.wbiea1797.

Maller, C. (2021) ‘The Multiple Values of Nature Turning things around: A discussion of values, practices, and action in the context of social-ecological change’, *People and Nature*, 00, pp. 1–13. Available at: https://doi.org/10.1002/pan3.10272.

Manfredo, M.J. *et al.* (2021) ‘Why social values cannot be changed for the sake of conservation’, *Conservation Biology*, 31(4), pp. 772–780. Available at: https://doi.org/10.1111/cobi.12855.

Martin-Ortega, J., Ojea, E. and Roux, C. (2013) ‘Payments for water ecosystem services in Latin America: A literature review and conceptual model’, *Ecosystem Services*, 6, pp. 122–132. Available at: https://doi.org/10.1016/j.ecoser.2013.09.008.

Martin, E. (1998) ‘Anthropology and the cultural study of science’, *Science Technology and Human Values*, 23(1), pp. 24–44. Available at: https://doi.org/10.1177/016224399802300102.

Martins, L. and Teixeira, C. (2023) ‘Agronejo: uma análise do sertanejo como elemento cultural do agronegócio’, *Intercom - Sociedade Brasileira de Estudoes*

Interdisciplinares da Comunicação, pp. 1–12.

Meijaard, E. *et al.* (2013) 'People's Perceptions about the Importance of Forests on Borneo', *PLoS ONE*, 8(9). Available at: https://doi.org/10.1371/journal.pone.0073008.

Merçon, J. (2025) 'Diverse values of nature and political ontology', *Ecology and Society*, 30(2). Available at: https://doi.org/10.5751/ES-16040-300213.

Mikołajczak, K. *et al.* (2021) 'Who knows, who cares? Untangling ecological knowledge and nature connection among Amazonian colonist farmers', *People and Nature*, 3(2), pp. 431–445. Available at: https://doi.org/10.1002/pan3.10183.

Mikołajczak, K.M. *et al.* (2023) 'Evaluating the influence of nature connection and values on conservation attitudes at a tropical deforestation frontier', *Conservation Biology*, (October 2022), pp. 1–14. Available at: https://doi.org/10.1111/cobi.14067.

Milkoreit, M. *et al.* (2018) 'Defining tipping points for social-ecological systems scholarship - An interdisciplinary literature review', *Environmental Research Letters*, 13(3). Available at: https://doi.org/10.1088/1748-9326/aaaa75.

Miller, B. (2011) *Cultural Anthropology*. 6th edn. Prentice Hall.

Milton, K. (1997) 'Ecologies: anthropology, culture and the environment', *International Social Science Journal*, 49(154), pp. 477–495. Available at: https://doi.org/https://doi.org/10.1111/j.1468-2451.1997.tb00039.x.

Moffette, F., Skidmore, M. and Gibbs, H.K. (2021) 'Environmental policies that shape productivity: Evidence from cattle ranching in the Amazon', *Journal of Environmental Economics and Management*, 109(May 2020), p. 102490. Available at: https://doi.org/10.1016/j.jeem.2021.102490.

Moore, R. (2004) 'Postmodernism and Punk Subculture: Cultures of Authenticity and Deconstruction', *Communication Review*, 7(3), pp. 305–327. Available at: https://doi.org/10.1080/10714420490492238.

Morais, B.K.D.E. (2020) 'A era do Sertanejo'.

Moran, P.A.. (1950) 'Notes on Continuous Stochastic Phenomena', *Biometrika*, 37(1–2), pp. 17–23. Available at: https://doi.org/https://doi.org/10.1093/biomet/37.1-2.17.

Morpurgo, J. *et al.* (2023) 'The role of elections as drivers of tropical deforestation',

Biological Conservation, 279(November 2022), p. 109832. Available at: https://doi.org/10.1016/j.biocon.2022.109832.

Nakamura, G. *et al.* (2023) 'Three pathways to better recognize the expertise of Global South researchers', *NPJ Biodiversity*, 2(1), pp. 1–4. Available at: https://doi.org/10.1038/s44185-023-00021-7.

Nanni, L. *et al.* (2016) 'Combining visual and acoustic features for music genre classification', *Expert Systems with Applications*, 45, pp. 108–117. Available at: https://doi.org/10.1016/j.eswa.2015.09.018.

Nascimento, M.N., Aukes, T.F.N. and McMichael, C.N.H. (2024) 'Indigenous and colonial influences on Amazonian forests', *Plants People Planet*, 6(4), pp. 803–823. Available at: https://doi.org/10.1002/ppp3.10515.

Nepstad, D. *et al.* (2014) 'Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains', *Science*, 344(6188), pp. 1118–1123. Available at: http://www.sciencemag.org.libaccess.sjlibrary.org/content/344/6188/1118.full.pdf.

Nepstad, D.C. *et al.* (1999) 'Large-scale impoverishment of amazonian forests by logging and fire', *Nature*, 398(6727), pp. 505–508. Available at: https://doi.org/10.1038/19066.

Nepstad, D.C., Stickler, C.M. and Almeida, O.T. (2006) 'Globalization of the Amazon soy and beef industries: Opportunities for conservation', *Conservation Biology*, 20(6), pp. 1595–1603. Available at: https://doi.org/10.1111/j.1523-1739.2006.00510.x.

Newton, P. *et al.* (2020) 'The Number and Spatial Distribution of Forest-Proximate People Globally', *One Earth*, 3(3), pp. 363–370. Available at: https://doi.org/10.1016/j.oneear.2020.08.016.

Nolan, K.A. and Callahan, J.E. (2006) 'Beachcomber Biology : The Shannon-Weiner Species Diversity Index', in *Proceedings of the 27th Workshop/Conference of the Association for Biology Laboratory Education (ABLE)*, pp. 334–338.

Nugent, S. (1993) *Amazonian Caboclo Society: An Essay on Invisibility and Peasant Economy*. Taylor & Francis. Available at: https://doi.org/https://doi.org/10.4324/9781003084440.

Nugent, S. (1995) *Big Mouth: The Amazon Speaks*. San Fransisco: San Frnasisco: Brown Trout Press. Available at: https://research.gold.ac.uk/id/eprint/11814/.

Nugent, S. (1997) 'The Coordinates of Identity in Amazonia: At play in the fields of culture', *Critique of Anthropology*, 17(1). Available at: https://doi.org/10.1177/0308275X9701700103.

Nugent, S. (2009) 'Indigenism and Cultural Authenticity in Brazilian Amazonia', p. 25. Available at: http://cms.gold.ac.uk/anthropology/garp/GARP15_web.pdf.

Nugent, S. (2010) 'Amazonia: Ecosystem and Social System', *Royal Anthropological Institute of Great Britain and Ireland*, 16(1), pp. 62–74. Available at: http://www.jstor.org/stable/2801975.

Nugent, S. (2017) *The Rise and Fall of the Amazon Rubber Industry*. Taylor & Francis. Available at: https://doi.org/10.4324/9781315179971.

Odeny, B. and Bosurgi, R. (2022) 'Time to end parachute science', *PLoS Medicine*, 19(9), pp. 10–12. Available at: https://doi.org/10.1371/journal.pmed.1004099.

Oliven, R.G. (2000) '"the largest popular culture movement in the Western world": intellectuals and Gaúcho Traditionalism in Brazil', *American Ethnologist*, 27(1), pp. 128–146. Available at: https://doi.org/10.1525/ae.2000.27.1.128.

Oliven, R.G. (2008) 'Two Sides of the Same Coin: Modern Gaúcho Identity in Brazil', *Perspectives on Las Américas: A Reader in Culture, History, & Representation*, 4(2), pp. 317–328. Available at: https://doi.org/10.1002/9780470753538.ch19.

Ono, A.J., Boyd, D.R. and Chan, K.M.A. (2023) 'Acculturation as an ecosystem service? Urban natural space supports evolving relational values and identity in new female migrants', *People and Nature*, 5(2), pp. 313–325. Available at: https://doi.org/10.1002/pan3.10188.

Ostrom, E. (1990) 'Governing the commons: the evolution of institutions for collective action', *Governing the commons: the evolution of institutions for collective action*, 32(2). Available at: https://doi.org/10.2307/3146384.

Otamendi-Urroz, I. *et al.* (2025) 'Exploring biocultural diversity: A systematic analysis and refined classification to inform decisions on conservation and sustainability', *Ambio*, 54(10), pp. 1581–1597. Available at: https://doi.org/10.1007/s13280-025-

02168-y.

Pacheco, L.M. and Gomes, C.V.A. (2023) 'The trajectory of Amazonia forest extractivists social movement: Shifting political struggle, strategies, demands and achievements', *Ambiente e Sociedade*, 26.

Pacheco, P. and Poccard-Chapuis, R. (2012) 'The Complex Evolution of Cattle Ranching Development Amid Market Integration and Policy Shifts in the Brazilian Amazon', *Annals of the Association of American Geographers*, 102(6), pp. 1366–1390. Available at: https://doi.org/10.1080/00045608.2012.678040.

Parry, L. *et al.* (2010) 'Rural-urban migration brings conservation threats and opportunities to Amazonian watersheds', *Conservation Letters*, 3(4), pp. 251–259. Available at: https://doi.org/10.1111/j.1755-263X.2010.00106.x.

Parry, L. *et al.* (2018) 'Social Vulnerability to Climatic Shocks Is Shaped by Urban Accessibility', *Annals of the American Association of Geographers*, 108(1), pp. 125–143. Available at: https://doi.org/10.1080/24694452.2017.1325726.

Parry, L. *et al.* (2025) 'Forest citizens and people-centered conservation in the Brazilian Amazon', *Conservation Biology*, 39(3), pp. 1–12. Available at: https://doi.org/10.1111/cobi.70031.

Parry, L., Barlow, J. and Pereira, H. (2014) 'Wildlife Harvest and Consumption in Amazonia's Urbanized Wilderness', *Conservation Letters*, 7(6), pp. 565–574. Available at: https://doi.org/10.1111/conl.12151.

Parry, L., Barlow, J. and Peres, C.A. (2009) 'Allocation of hunting effort by Amazonian smallholders: Implications for conserving wildlife in mixed-use landscapes', *Biological Conservation*, 142(8), pp. 1777–1786. Available at: https://doi.org/10.1016/j.biocon.2009.03.018.

Parry, L. and Peres, C.A. (2015) 'Evaluating the use of local ecological knowledge to monitor hunted tropicalforest wildlife over large spatial scales', *Ecology and Society*, 20(3), p. 15. Available at: https://doi.org/10.5751/ES-07601-200315.

Pascual, U. *et al.* (2017) 'Valuing nature's contributions to people: the IPBES approach', *Current Opinion in Environmental Sustainability*, 26–27, pp. 7–16. Available at: https://doi.org/10.1016/j.cosust.2016.12.006.

Pascual, U. *et al.* (2023) 'Diverse values of nature for sustainability', *Nature*, 620(7975), pp. 813–823. Available at: https://doi.org/10.1038/s41586-023-06406-9.

Patterson, O. (2014) 'Making sense of culture', *Annual Review of Sociology*, 40, pp. 1–30. Available at: https://doi.org/10.1146/annurev-soc-071913-043123.

Pavão, F. (2022) *Mais de 35 cidades têm shows investigados; Gusttavo Lima é o mais citado*, *Splash*. Available at: https://www.uol.com.br/splash/noticias/2022/06/12/cpi-do-sertanejo-shows-investigados.htm?cmpid=copiaecola (Accessed: 17 September 2025).

Pelchat, N. and Gelowitz, C.M. (2020) 'Neural Network Music Genre Classification', *Canadian Journal of Electrical and Computer Engineering*, 43(3), pp. 170–173. Available at: https://doi.org/10.1109/CJECE.2020.2970144.

Peluso, D.M. (2015) 'Circulating between rural and urban communities: Multisited dwellings in amazonian frontiers', *Journal of Latin American and Caribbean Anthropology*, 20(1), pp. 57–79. Available at: https://doi.org/10.1111/jlca.12134.

Pendrill, F. *et al.* (2022) 'Disentangling the numbers behind agriculture-driven tropical deforestation', *Science*, 377(6611). Available at: https://doi.org/10.1126/science.abm9267.

Pereira, J.C. and Terrenas, J. (2022) 'Towards a transformative governance of the Amazon', *Global Policy*, 13(S3), pp. 60–75. Available at: https://doi.org/10.1111/1758-5899.13163.

Pereira, R. *et al.* (2020) 'Extensive Production Practices and Incomplete Implementation Hinder Brazil's Zero-Deforestation Cattle Agreements in Pará', *Tropical Conservation Science*, 13. Available at: https://doi.org/10.1177/1940082920942014.

Pereira, R., Simmons, C.S. and Walker, R. (2016) 'Smallholders, agrarian reform, and globalization in the Brazilian amazon: Cattle versus the environment', *Land*, 5(3), pp. 1–15. Available at: https://doi.org/10.3390/land5030024.

Pereira Santos, R. (2023) *Grilagem de Terras na Amazônia: Fragilidades Jurídicas da Lei 10.267/01 Num Estudo de Caso de Deslocamento de Títulos Centenários no Município de Lábrea, AM*. Available at: https://doi.org/https://tede.ufam.edu.br/handle/tede/9687.

Phillips, D. (2019) ‘Bolsonaro declares ’ the Amazon is ours ’ and calls deforestation data ’ lies ’’, *The Guardian online*, pp. 1–5.

Pichl, M. *et al.* (2017) ‘Mining Culture-Specific Music Listening Behavior from Social Media Data’, *Proceedings - 2017 IEEE International Symposium on Multimedia, ISM 2017*, 2017-Janua, pp. 208–215. Available at: https://doi.org/10.1109/ISM.2017.35.

Piva da Silva, M., Fraser, J.A. and Parry, L. (2022) ‘From “prison” to “paradise”? Seeking freedom at the rainforest frontier through urban–rural migration’, *World Development*, 160. Available at: https://doi.org/10.1016/j.worlddev.2022.106077.

Plumwood, V. (2006) ‘The Concept of a Cultural Landscape: Nature, Culture and Agency in the Land’, *Ethics & the Environment*, 11(2), pp. 115–150. Available at: https://doi.org/10.2979/ete.2006.11.2.115.

Pokorny, B., Scholz, I. and de Jong, W. (2013) ‘REDD+ for the poor or the poor for REDD+? About the limitations of environmental policies in the Amazon and the potential of achieving environmental goals through pro-poor policies’, *Ecology and Society*, 18(2). Available at: https://doi.org/10.5751/ES-05458-180203.

le Polain de Waroux, Y. *et al.* (2019) ‘The Restructuring of South American Soy and Beef Production and Trade Under Changing Environmental Regulations’, *World Development*, 121, pp. 188–202. Available at: https://doi.org/10.1016/j.worlddev.2017.05.034.

le Polain de Waroux, Y. *et al.* (2021) ‘The role of culture in land system science’, *Journal of Land Use Science*, 00(00), pp. 1–17. Available at: https://doi.org/10.1080/1747423X.2021.1950229.

Posey, D. *et al.* (1984) ‘Ethnoecology as Applied Anthropology in Amazonian Development’, *Human Organization*, 43(2), pp. 95–107. Available at: https://doi.org/10.17730/humo.43.2.908kp82611x0w860.

Pratzer, M. *et al.* (2023) ‘Agricultural intensification, Indigenous stewardship and land sparing in tropical dry forests’, *Nature Sustainability*, 6(6), pp. 671–682. Available at: https://doi.org/10.1038/s41893-023-01073-0.

Preiser, R. *et al.* (2018) ‘Social-ecological systems as complex adaptive systems: Organizing principles for advancing research methods and approaches’, *Ecology and*

Society, 23(4). Available at: https://doi.org/10.5751/ES-10558-230446.

Preston, C.J. (1998) 'Epistemology and intrinsic values: Norton and Callicott's critiques of Rolston', *Environmental Ethics*, 20(4), pp. 409–428. Available at: https://doi.org/10.5840/enviroethics19982047.

Rangel, J.M.L., do Nascimento, A.L.B. and Ramos, M.A. (2024) 'The influence of urbanization on local ecological knowledge: a systematic review', *Journal of Ethnobiology and Ethnomedicine*, 20(1). Available at: https://doi.org/10.1186/s13002-024-00747-z.

Raymond, C.M. *et al.* (2023) 'An inclusive typology of values for navigating transformations towards a just and sustainable future', *Current Opinion in Environmental Sustainability*, 64(Ivic), p. 101301. Available at: https://doi.org/10.1016/j.cosust.2023.101301.

Reed, J. *et al.* (2019) 'Engaging multiple stakeholders to reconcile climate, conservation and development objectives in tropical landscapes', *Biological Conservation*, 238(August), p. 108229. Available at: https://doi.org/10.1016/j.biocon.2019.108229.

Reis, R.G. and Leal, M.L.M. (2020) 'Análise das relações de focos de calor e desflorestamento no município de Lábrea, sul do Amazonas', *Revista Brasileira de Meio Ambiente Reis*, 8, pp. 038–053. Available at: https://www.revistabrasileirademeioambiente.com/index.php/RVBMA/article/view/356.

Reise, S.P. (2012) 'The Rediscovery of Bifactor Measurement Models', *Multivariate Behavioral Research*, 47(5), pp. 667–696. Available at: https://doi.org/10.1080/00273171.2012.715555.

Ribas, C.C. *et al.* (2025) 'The role of rivers in the origin and future of Amazonian biodiversity', *Nature Reviews Biodiversity*, 1(January), pp. 14–31. Available at: https://doi.org/10.1038/s44358-024-00001-0.

Riechers, M. *et al.* (2020) 'The erosion of relational values resulting from landscape simplification', *Landscape Ecology*, 35(11), pp. 2601–2612. Available at: https://doi.org/10.1007/s10980-020-01012-w.

Robbins, P. (2019) *Political Ecology: A Critical Introduction*. John Wiley & Sons.

Rodrigues-Filho, S. *et al.* (2015) 'Election-driven weakening of deforestation control in

the Brazilian Amazon', *Land Use Policy*, 43, pp. 111–118. Available at: https://doi.org/10.1016/j.landusepol.2014.11.002.

Rodrigues, A.S.L. *et al.* (2009) 'Boom-and-bust development patterns across the amazon deforestation frontier', *Science*, 324(5933), pp. 1435–1437. Available at: https://doi.org/10.1126/science.1174002.

Rodrigues, M. (2023) 'Will Brazil's President Lula Keep His Climate Promises?', *Nature*, 613(7944), pp. 420–421.

Ronchetti, E.. and Huber, P.. (2009) *Robust Statistics*. John Wiley & Sons.

de Sá Guimarães, F. *et al.* (2023) 'The evangelical foreign policy model: Jair Bolsonaro and evangelicals in Brazil', *Third World Quarterly*, 44(6), pp. 1324–1344. Available at: https://doi.org/10.1080/01436597.2023.2181154.

Saerchinger, C. (1938) 'Radio as a Political Instrument', *Foreign Affairs*, 16(2), pp. 244–259.

Salisbury, D.S. and Schmink, M. (2007) 'Cows versus rubber: Changing livelihoods among Amazonian extractivists', *Geoforum*, 38(6), pp. 1233–1249. Available at: https://doi.org/10.1016/j.geoforum.2007.03.005.

Sanches, R.A., Futemma, C.R.T. and Alves, H.Q. (2021) 'Indigenous territories and governance of forest restoration in the Xingu River (Brazil)', *Land Use Policy*, 104(June 2020). Available at: https://doi.org/10.1016/j.landusepol.2020.104755.

Santos, A.M. dos *et al.* (2021) 'Deforestation drivers in the Brazilian Amazon: assessing new spatial predictors', *Journal of Environmental Management*, 294(June). Available at: https://doi.org/10.1016/j.jenvman.2021.113020.

Scales, I.R. (2012) 'Lost in translation: Conflicting views of deforestation, land use and identity in western Madagascar', *Geographical Journal*, 178(1), pp. 67–79. Available at: https://doi.org/10.1111/j.1475-4959.2011.00432.x.

Schaan, D. (2010) 'Long-term human induced impacts on Marajó Island landscapes, Amazon estuary', *Diversity*, 2(2), pp. 182–206. Available at: https://doi.org/10.3390/d2020182.

Schang, K.A. *et al.* (2020) 'Ecological research should consider Indigenous peoples and

stewardship', *Facets*, 5(1), pp. 534–537. Available at: https://doi.org/10.1139/FACETS-2019-0041.

Schmink, M. (1982) 'Land Conflicts in Amazonia', *American Ethnologist*, 9(2), pp. 341–357.

Schmink, M. (2003) 'No Longer Invisible, But Still Enigmatic: Amazonian Peasant Identities and Cosmographies', *Reviews in Anthropology*, 32(3), pp. 223–237. Available at: https://doi.org/10.1080/00988150390230318.

Schmink, M. *et al.* (2008) 'Forest Citizenship in Acre, Brazil', in *Forests Under Pressure - Local Responses to Global Issues*, pp. 31–47.

Schmink, M. (2011) 'Forest Citizens: Changing Life Conditions and Social Identities in the Land of the Rubber Tappers', *Latin American Research Review*, 46, pp. 141–158. Available at: https://doi.org/10.1353/lar.2011.0035.

Schmink, M. *et al.* (2019) 'From contested to "green" frontiers in the Amazon? A long-term analysis of São Félix do Xingu, Brazil', *Journal of Peasant Studies*, 46(2), pp. 377–399. Available at: https://doi.org/10.1080/03066150.2017.1381841.

Schmink, M. (2019) 'The socioeconomic matrix of deforestation', *Population and Environment: Rethinking the Debate*, (June 2019), pp. 253–275. Available at: https://doi.org/10.4324/9780429302602-11.

Schmink, M. and Wood, C.H. (1992) *Contested Frontiers in Amazonia*. Columbia University Press, New York.

Schulz, C. and Martin-Ortega, J. (2018) 'Quantifying relational values — why not?', *Current Opinion in Environmental Sustainability*, 35(December 2017), pp. 15–21. Available at: https://doi.org/10.1016/j.cosust.2018.10.015.

Sen, A.K. (1977) 'Rational Fools : A Critique of the Behavioral Foundations of Economic Theory Author (s): Amartya K . Sen Published by : Wiley Stable URL : http://www.jstor.org/stable/2264946 REFERENCES Linked references are available on JSTOR for this article : You may', *Philosophy & Public Affairs*, 6(4), pp. 317–344. Available at: http://www.jstor.org/stable/2264946?seq=1&cid=pdf-reference#references_tab_contents.

Seweryn, O. (2007) 'Identity Change as a Consequence of the Migration Experience', in

Imagining Frontiers, Contesting Identities. Pisa University Press, pp. 21–42.

Seymour, F. and Harris, N.L. (2019) 'Reducing tropical deforestation', *Science*, 365(6455), pp. 756–757. Available at: https://doi.org/10.1126/science.aax8546.

Shaikh, S.F.E.A. *et al.* (2021) 'Accounting for spatial autocorrelation is needed to avoid misidentifying trade-offs and bundles among ecosystem services', *Ecological Indicators*, 129. Available at: https://doi.org/10.1016/j.ecolind.2021.107992.

Sheikh, P.A., Merry, F.D. and McGrath, D.G. (2006) 'Water buffalo and cattle ranching in the Lower Amazon Basin: Comparisons and conflicts', *Agricultural Systems*, 87(3), pp. 313–330. Available at: https://doi.org/10.1016/j.agsy.2005.02.003.

Siegmund-Schultze, M. *et al.* (2007) 'Cattle are cash generating assets for mixed smallholder farms in the Eastern Amazon', *Agricultural Systems*, 94(3), pp. 738–749. Available at: https://doi.org/10.1016/j.agsy.2007.03.005.

Silva-Junior, C.H.L. *et al.* (2023) 'Brazilian Amazon indigenous territories under deforestation pressure', *Scientific Reports*, 13(1), pp. 1–9. Available at: https://doi.org/10.1038/s41598-023-32746-7.

Silva Junior, C.H.L. *et al.* (2020) 'Amazon forest on the edge of collapse in the Maranhão State, Brazil', *Land Use Policy*, 97(January), p. 104806. Available at: https://doi.org/10.1016/j.landusepol.2020.104806.

Skidmore, M.E. *et al.* (2021) 'Cattle ranchers and deforestation in the Brazilian Amazon: Production, location, and policies', *Global Environmental Change*, 68, p. 102280. Available at: https://doi.org/10.1016/j.gloenvcha.2021.102280.

Skutsch, M. and Turnhout, E. (2020) 'REDD+: If communities are the solution, what is the problem?', *World Development*, 130, p. 104942. Available at: https://doi.org/10.1016/j.worlddev.2020.104942.

Smith, A.E. and Veldman, R.G. (2020) 'Evangelical Environmentalists? Evidence from Brazil', *Journal for the Scientific Study of Religion*, 59(2), pp. 341–359. Available at: https://doi.org/10.1111/jssr.12656.

De Souza Martins, J. (2002) *Representing the peasantry? Struggles for/about land in Brazil*, *Journal of Peasant Studies*. Available at: https://doi.org/10.1080/03066150412331311099.

Spaargaren, G. (2011) ‘Theories of practices: Agency, technology, and culture. Exploring the relevance of practice theories for the governance of sustainable consumption practices in the new world-order’, *Global Environmental Change*, 21(3), pp. 813–822. Available at: https://doi.org/10.1016/j.gloenvcha.2011.03.010.

Steward, A. (2007) ‘Nobody farms here anymore: Livelihood diversification in the Amazonian community of Carvão, a historical perspective’, *Agriculture and Human Values*, 24(1), pp. 75–92. Available at: https://doi.org/10.1007/s10460-006-9032-2.

Stewart, I. *et al.* (2019) ‘Rock, rap, or reggaeton?: Assessing Mexican immigrants’ cultural assimilation using Facebook data’, *The Web Conference 2019 - Proceedings of the World Wide Web Conference, WWW 2019*, (May), pp. 3258–3264. Available at: https://doi.org/10.1145/3308558.3313409.

Szaboova, L., Brown, K. and Fisher, J.A. (2020) ‘Access to Ecosystem Benefits: More than Proximity’, *Society and Natural Resources*, 33(2), pp. 244–260. Available at: https://doi.org/10.1080/08941920.2018.1556759.

Tallman, P.S. *et al.* (2022) ‘Ecosyndemics: The potential synergistic health impacts of highways and dams in the Amazon’, *Social Science and Medicine*, 295(May 2020). Available at: https://doi.org/10.1016/j.socscimed.2020.113037.

Tavakol, M. and Wetzel, A. (2020) ‘Factor Analysis: a means for theory and instrument development in support of construct validity’, *International journal of medical education*, 11, pp. 245–247. Available at: https://doi.org/10.5116/ijme.5f96.0f4a.

Teixeira, A. *et al.* (2023) ‘Pro-Environmental Behaviors: Relationship With Nature Visits, Connectedness to Nature and Physical Activity’, *American Journal of Health Promotion*, 37(1), pp. 12–29. Available at: https://doi.org/10.1177/08901171221119089.

Tengö, M. *et al.* (2017) ‘Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability’, *Current Opinion in Environmental Sustainability*, 26–27, pp. 17–25. Available at: https://doi.org/10.1016/j.cosust.2016.12.005.

Tew, E.R., Simmons, B.I. and Sutherland, W.J. (2019) ‘Quantifying cultural ecosystem services: Disentangling the effects of management from landscape features’, *People and Nature*, 1(1), pp. 70–86. Available at: https://doi.org/10.1002/pan3.14.

Thaler, G.M. (2017) ‘The Land Sparing Complex: Environmental Governance, Agricultural Intensification, and State Building in the Brazilian Amazon’, *Annals of the American Association of Geographers*, 107(6), pp. 1424–1443. Available at: https://doi.org/10.1080/24694452.2017.1309966.

Thaler, G.M. (2024) *Saving a Rainforest and Losing the World: Conservation and Displacement in the Global Tropics*. Yale University Press.

Thaler, G.M., Viana, C. and Toni, F. (2019) ‘From frontier governance to governance frontier: The political geography of Brazil’s Amazon transition’, *World Development*, 114, pp. 59–72. Available at: https://doi.org/10.1016/j.worlddev.2018.09.022.

Thomas, K. (2017) ‘Sounds of disadvantage: Musical taste and the origins of ethnic difference’, *Poetics*, 60, pp. 29–47. Available at: https://doi.org/10.1016/j.poetic.2016.10.002.

Thomaz, S.M. *et al.* (2012) ‘Using space-for-time substitution and time sequence approaches in invasion ecology’, *Freshwater Biology*, 57(11), pp. 2401–2410. Available at: https://doi.org/10.1111/fwb.12005.

Tiki, W., Oba, G. and Tvedt, T. (2011) ‘Human stewardship or ruining cultural landscapes of the ancient Tula wells, southern Ethiopia’, *Geographical Journal*, 177(1), pp. 62–78. Available at: https://doi.org/10.1111/j.1475-4959.2010.00369.x.

Tillman, R.H. (1980) ‘Punk rock and the construction of “pseudopolitical” movements’, *Popular Music and Society*, 7(3), pp. 165–175. Available at: https://doi.org/10.1080/03007768008591160.

Tobler, W.. (1970) ‘A Computer Movie Simulating Urban Growth in the Detroit Region’, *Economic Geography*, 46, pp. 234–240. Available at: https://www.jstor.org/stable/143141.

Tosi Roquette, M.E. and McCall, M.K. (2021) ‘Participatory Mapping: Supporting Community Identity Through a Focus on Territory. An Indigenous Tupiniquim Community in Espírito Santo, Brazil’, pp. 195–218. Available at: https://doi.org/10.1007/978-3-030-82222-4_12.

Uehara, T., Sakurai, R. and Tsuge, T. (2020) ‘Cultivating relational values and sustaining socio-ecological production landscapes through ocean literacy: a study on

Satoumi', *Environment, Development and Sustainability*, 22(2), pp. 1599–1616. Available at: https://doi.org/10.1007/s10668-018-0226-8.

Uhl, C. and Vieira, I.C.G. (1989) 'Ecological Impacts of Selective Logging in the Brazilian Amazon: A Case Study from the Paragominas Region of the State of Para', *Biotropica*, 21(2), pp. 98–106.

Vadjunec, J.M., Schmink, M. and Greiner, A.L. (2012) 'New Amazonian geographies: emerging identities and landscapes', in *Amazonian Geographies*. Routledge, p. 20.

Vale, P. *et al.* (2019) 'The Expansion of Intensive Beef Farming to the Brazilian Amazon', *Global Environmental Change*, 57(June), p. 101922. Available at: https://doi.org/10.1016/j.gloenvcha.2019.05.006.

Vanner, C. (2015) 'Positionality at the Center: Constructing an Epistemological and Methodological Approach for a Western Feminist Doctoral Candidate Conducting Research in the Postcolonial', *International Journal of Qualitative Methods*, 14(4), pp. 1–12. Available at: https://doi.org/10.1177/1609406915618094.

Veiga, J.B. *et al.* (2002) 'Cattle Ranching in the Amazon Region', *Anim. Prod. Aust.*, 24(April), pp. 253–256. Available at: https://globalforestatlas.yale.edu/amazon/land-use/cattle-ranching.

Viana, C. *et al.* (2016) 'How Does Hybrid Governance Emerge? Role of the elite in building a Green Municipality in the Eastern Brazilian Amazon', *Environmental Policy and Governance*, 26(5), pp. 337–350. Available at: https://doi.org/10.1002/eet.1720.

Vieira, C. *et al.* (2020) 'Using Facebook Data to Measure Cultural Distance between Countries: The Case of Brazilian Cuisine', *The Web Conference 2020 - Proceedings of the World Wide Web Conference, WWW 2020*, pp. 3091–3097. Available at: https://doi.org/10.1145/3366423.3380082.

Virtanen, P.K. *et al.* (2025) 'Indigenous governance and relationality have effectively avoided forest loss in the Southwest Amazon', *Communications Earth and Environment*, 6(1), pp. 1–15. Available at: https://doi.org/10.1038/s43247-025-02174-8.

de Vos, A. (2022) 'Stowing parachutes, strengthening science', *Conservation Science and Practice*, 4(5), pp. 3–5. Available at: https://doi.org/10.1111/csp2.12709.

de Vos, A. and Schwartz, M.W. (2022) 'Confronting parachute science in

conservation', *Conservation Science and Practice*, 4(5), pp. 3–6. Available at: https://doi.org/10.1111/csp2.12681.

Walker, N.F., Patel, S.A. and Kalif, K.A.B. (2013) 'From Amazon pasture to the high street: Deforestation and the brazilian cattle product supply chain', *Tropical Conservation Science*, 6(3), pp. 446–467. Available at: https://doi.org/10.1177/194008291300600309.

Waters, M.C. and Jiménez, T.R. (2005) 'Assessing immigrant assimilation: New empirical and theoretical challenges', *Annual Review of Sociology*, 31, pp. 105–125. Available at: https://doi.org/10.1146/annurev.soc.29.010202.100026.

Watson, M.K. (2015) *From Rural Street Theater to Big City Extravaganza: The Meaning of The Manaus Boi-Bumbá In An Urbanazing Brazil*, *University of New Mexico*.

Watson, M.K. (2018) '"It tells all of our history!" the boi-bumbá festival of manaus', *Journal of Anthropological Research*, 74(1), pp. 74–99. Available at: https://doi.org/10.1086/696222.

Way, S.F. *et al.* (2019) 'Environmental changes and the dynamics of musical identity', *Proceedings of the 13th International Conference on Web and Social Media, ICWSM 2019*, (Icwsm), pp. 527–536.

West, S. *et al.* (2020) 'A relational turn for sustainability science? Relational thinking, leverage points and transformations', *Ecosystems and People*, 16(1), pp. 304–325. Available at: https://doi.org/10.1080/26395916.2020.1814417.

West, S. *et al.* (2024) 'Relational approaches to sustainability transformations: walking together in a world of many worlds', *Ecosystems and People*, 20(1). Available at: https://doi.org/10.1080/26395916.2024.2370539.

Westerink, J. *et al.* (2021) 'Can a "good farmer" be nature-inclusive? Shifting cultural norms in farming in The Netherlands', *Journal of Rural Studies*, 88, pp. 60–70. Available at: https://doi.org/10.1016/J.JRURSTUD.2021.10.011.

Whitehead, A.L. *et al.* (2014) 'Integrating biological and social values when prioritizing places for biodiversity conservation', *Conservation Biology*, 28(4), pp. 992–1003. Available at: https://doi.org/10.1111/cobi.12257.

Wood, C.H. and Schmink, M. (1993) 'The Military And The Environment In The Brazilian Amazon', *Journal of Political & Military Sociology*, 21(1), pp. 81–105.

Wu, J. (2010) 'Landscape of culture and culture of landscape: Does landscape ecology need culture?', *Landscape Ecology*, 25(8), pp. 1147–1150. Available at: https://doi.org/10.1007/s10980-010-9524-8.

Wu, J. (2019) 'Linking landscape, land system and design approaches to achieve sustainability', *Journal of Land Use Science*, 14(2), pp. 173–189. Available at: https://doi.org/10.1080/1747423X.2019.1602677.

Yong, A.G. and Pearce, S. (2013) 'A Beginner's Guide to Factor Analysis: Focusing on Exploratory Factor Analysis', *Tutorials in Quantitative Methods for Psychology*, 9(2), pp. 79–94. Available at: https://doi.org/10.20982/tqmp.09.2.p079.

Yuliani, E.L. *et al.* (2018) 'Keeping the land: indigenous communities ' struggle over land use and sustainable forest management in Kalimantan , Indonesia', *Ecology and Society*, 23(4).

Yuliani, E.L. *et al.* (2020) 'Land Use Policy Forest or oil palm plantation? Interpretation of local responses to the oil palm promises in Kalimantan, Indonesia', *Land Use Policy*, 96(March), p. 104616. Available at: https://doi.org/10.1016/j.landusepol.2020.104616.

Yuliani, E.L. *et al.* (2023) 'Relational values of forests: Value- -conflicts between local communities and external programmes in Sulawesi', *People and Nature*, 5, pp. 1822–1838. Available at: https://doi.org/10.1002/pan3.10389.

Zafra-Calvo, N. *et al.* (2020) 'Plural valuation of nature for equity and sustainability: Insights from the Global South', *Global Environmental Change*, 63(April), p. 102115. Available at: https://doi.org/10.1016/j.gloenvcha.2020.102115.

Zagaria, A. (2021) 'What Do We Talk About When We Talk About Culture? There is a Missing Link Between the Natural and the Social Sciences', *Integrative Psychological and Behavioral Science*, 55(4), pp. 850–857. Available at: https://doi.org/10.1007/s12124-021-09644-6.

Zammito, J.H. (2004) *A Nice Derangement of Epistemes: Post-positivism in the Study of Science from Quine to Latour*. University of Chicago Press. Available at: https://books.google.co.uk/books?id=iXxK6e07ciUC&dq=postpositivism&lr=&source=

gbs_navlinks_s.

Zinbarg, R.E. *et al.* (2005) ‘Cronbach’s, α Revelle’s β and McDonald’s ω H: Their relations with each other and two alternative conceptualizations of reliability’, *Psychometrika*, 70(1), pp. 123–133. Available at: https://doi.org/10.1007/s11336-003-0974-7.

Zumak, A. *et al.* (2025) ‘Riverine communities in the Central Amazon are largely subject to erosion and sedimentation risk’, *Communications Earth and Environment*, 6(1). Available at: https://doi.org/10.1038/s43247-025-02058-x.

Zycherman, A. (2016) ‘Cultures of soy and cattle in the context of reduced deforestation and agricultural intensification in the Brazilian amazon’, *Environment and Society: Advances in Research*, 7(1), pp. 71–88. Available at: https://doi.org/10.3167/ares.2016.070105.