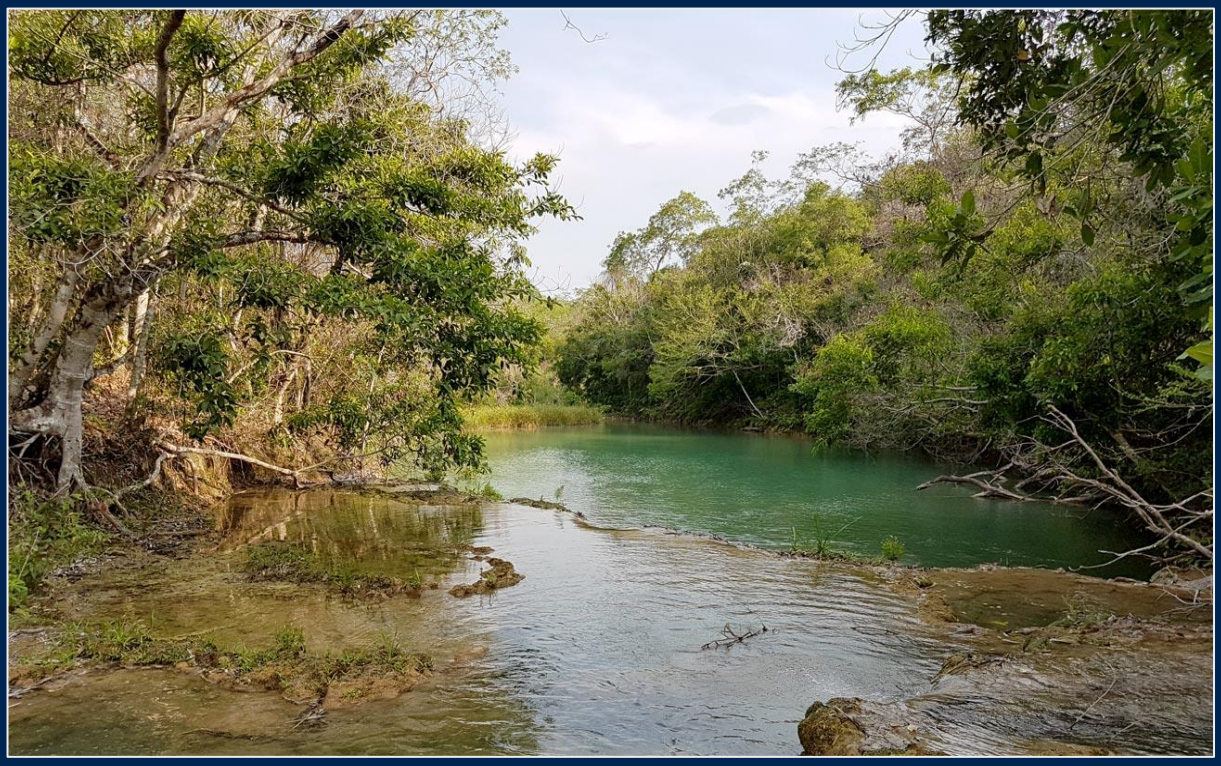
PARACEL CRITICAL HABITAT ASSESSMENT

For international Lender biodiversity safeguards alignment and FSC/Verra CCB product certification validation



KEY FINDINGS

- Paracel properties contain some good condition natural areas of the threatened 'Cerrados de Concepción' ecosystem which represent Critical Habitat
- Multiple threatened species are confirmed present in the landscape; none are thought abundant enough in the Area of Analysis to qualify Critical Habitat zones for them
- Paracel's Plantation Development Plans avoid most natural areas. Early assessments find excellent conservation opportunities exist within the Paracel set-asides and the wider landscape to align with the IFC PS6 & Verra CCB biodiversity Net Gain targets

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Nature Positive

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Table of contents

List of Figures iii
List of Tables iii
Acronym table iii
1. Executive summary i
Main findings i
Purpose and Methods of this Assessment iv
Implications of findings iv
Net Gain Strategy v
Recommendations and next steps ix
2. Project Description 1
3. Methods 2
Summary 2
Identifying an appropriate Area of Analysis 2
CH criteria & thresholds assessment 2
Constraints and limitations of this CHA 4
4. Results Summary 5
Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species 5
Criterion 2: Endemic or restricted-range species 7
Criterion 3: Migratory or congregatory species 7
Criterion 4: Highly threatened and/or unique ecosystems 8
Criterion 5: Key evolutionary processes 9
Species of national interest or stakeholder concern 9
Protected areas and internationally recognised areas 9
Natural and Modified Habitat identification 11
5. References 13
Appendix 1: Vegetation mapping and ground verification techniques 15
Appendix 2: Justifications for species qualification results under IFC criteria 1 & 2 31
Appendix 3: Historical Land Use – Land Cover analysis (1985-2021) methods description & maps 39

List of Figures

Figure 1: Map showing the Area of Analysis (the Aquidabán ecoregion) with location of Paracel properties, protected areas, and other areas of conservation interest (KBAs).....iii

Figure 2: Paracel's 20 properties – the 19 properties clustered to the NE are for plantation development and Zapatero Cué in the SW is the Mill site.....vii

Figure 3: Simplified Land Cover map based on 2022 validated landcover map (20 classes).....viii

Figure 4: (Appendix 1) Matrix showing the distribution of the vegetation classes estimated (rows) and observed (columns) after the field validation process.....29

List of Tables

Table 1. PS6 Critical Habitat criteria thresholds and descriptions.....3

Table 2. Species that possibly qualify the AoA as Critical Habitat under Criterion 1a.....5

Table 3. Species that likely, or possibly qualify the AoA as Critical Habitat under Criterion 1c.....6

Table 4. Species that likely, or possibly qualify the AoA as Critical Habitat under Criterion 2.....7

Table 5: (Appendix 1) List of first iteration modelled vegetation classes validated in the field.....28

Table 6: (Appendix 1) Post validation vegetation classes and aggregated classes for simplified mapping in Figure 3.....29

Table 7: (Appendix 2) Justifications for Species qualification results under IFC criteria 1 & 2.....31

Acronym table

Acronym	Definition
AE	Amenazada de Extinción (Paraguayan national species status)
AoA	Area of Analysis
BAP	Biodiversity Action Plan
BMEP	Biodiversity Monitoring and Evaluation Plan
BSI	Bare Soil Index
CCB	Climate Community & Biodiversity standard (Verra certification)
CH	Critical Habitat
CHA	Critical Habitat Assessment
CR	Critically Endangered (IUCN status)
EN	Endangered (IUCN status)
EP	En Peligro de extinción (Paraguayan national species status)
ESAP	Environmental and Social Action Plan
ESIA	Environmental and Social Impact Assessment
FSC	Forest Stewardship Council
GBIF	Global Biodiversity Information Facility
GEDI	Global Ecosystem Dynamics Investigation
GEE API	Google Earth Engine Application Programming Interface
IBAT	Integrated Biodiversity Assessment Tool
IFC	International Finance Corporation (World Bank Group)
IUCN	International Union for Conservation of Nature (IUCN)
KBA	Key Biodiversity Area (IUCN designation)
LULC	Land Use Land Cover

MADES	Ministerio del Ambiente y Desarrollo Sostenible (of Paraguay)
MNDWI	Modified Normalized Difference Water Index
NDBI	Normalized Difference Built-up Index
NDVI	Normalized Difference Vegetation Index
NG	Net Gain
NT	Near Threatened (IUCN status)
PS	Performance Standards
PS6	Performance Standard 6
RGB	Red, Green, and Blue
SWIR	Short Wave Infrared Band
VCS	Verified Carbon Standard (Verra certification)
VU	Vulnerable (IUCN status)

1. Executive summary

The Paracel Project ('the Project') is a large forestry and industrial project located in the Departments of Concepción and Amambay, within the Cerrados de Concepción ecosystem of north-eastern Paraguay. The Project's industrial component is a pulp mill with a capacity of 1.5 million tons per year of bleached pulp. The forestry component is eucalyptus trees grown on a 7-year rotational cycle within 19 properties owned by the company (c. 90,000 ha planted out of a 188,000 ha estate) (Figures 1 and 2), and a similar additional planted area owned by private landowners in the region whom Paracel will contract to supply wood ('Outgrowers').

Paracel leadership understands the Cerrados de Concepción ecosystem the Project is operating in has high biodiversity conservation value and is threatened by high rates of unsustainable land management and land-use change. Paracel aims to meet global best practice for the environmental and social outcomes of its operations and the International Finance Corporation Performance Standards are applied to all components of the project. In addition, the Project is pursuing certification under Verra's Verified Carbon Standard (VCS) and Climate, Community and Biodiversity (CCB) Standards for afforestation-reforestation and conservation carbon credits, and Forest Stewardship Council (FSC) for its cellulose pulp product.

Paracel is investing in staff and a series of studies involving Paraguayan and international experts to design the pathway to alignment with the International Finance Corporation (IFC)'s Performance Standard 6 (PS6). These studies also represent significant additional conservation value given the lack of natural history knowledge of the local ecosystem prior to the Project's presence.

Main findings

The Cerrados de Concepción form the southernmost tongue of the Cerrado biome extending south from Brazil. They are transitional with the Chaco and Atlantic Forest biomes to the west and east respectively. These Cerrados are characterised by a complex mosaic of forest and savanna habitat types where soil, topography, biogeography, and disturbance history are expressed in gradients of vegetation height, density, woodiness, and ground wetness. Forest canopies are both open (Cerradón) and closed (with a distinct riparian type), and a range of interwoven 'savanna formation' habitats (Campo Cerrado, Campo Sucio, high savannas, and flooded or seasonally flooded savannas) are characterised by different densities of sub-shrubs, shrubs, trees, and palms in addition to the native grasses & herbs.

Using the Aquidabán Ecoregion[1] as the Area of Analysis (Figure 1), Critical Habitat is designated because analysis of historical satellite imagery by Nature Positive shows high rates of natural land cover change[2]. These rates would qualify the ecosystem as having a 'Vulnerable' Threatened Status under the International Union for Conservation of Nature (IUCN) Red List of Ecosystems (RLE) criteria. Based on an extrapolation of the 36-year period studied to the 50 years' reference timeframe used by the RLE gives an estimate of 39[3]% loss of natural habitat[4], with rates accelerating over the last 10-20 years in some parts of the region.

[1] This ecoregion has a unique and highly diverse community of fauna and flora and contains the entire Cerrados de Concepción ecosystem and its bordering transition zones and is approximately ten times the area of the total Paracel estate.

[2] Analysis, conducted by Nature Positive, of broad land cover classes covered the 36-year period between 1985 and 2021 (or 2019 in Paracel properties which had started forestry development) as the longest period attainable with reasonably comparable imagery.

[3] This figure has a mean uncertainty among the three data sets used of 22% and includes forests degraded enough to become to semi-natural open habitats. Disaggregating the analysis by land tenure type shows the habitat loss rate varies markedly with tenure, including for example a three-fold higher rate of habitat loss in public versus private protected areas.

[4] The analysis counted loss as either natural forest cover removal, or conversion of savanna habitats into modified land cover. No estimation of condition was made.

Species assessment against Critical Habitat criteria consisted of a detailed literature-based screening of species recorded or predicted to occur in the Area of Analysis, producing a shortlist then subject to extensive expert consultation. The assessment indicates that none of the threatened species[5] confirmed as present in the landscape[6] (either by the impact assessment baseline or Paracel's subsequent biodiversity monitoring information) are likely to be in numbers to qualify the area as Critical Habitat based on PS6 species population thresholds. For the 15 species which are 'likely' and the further 29 that could 'possibly' qualify the AoA as containing Critical Habitat, monitoring information generated by the project should be utilised to confirm the level of concern.

Owing to Critical Habitat designation in this case being by ecosystem and not individual species, it is interpreted as being represented by viable patches (size and connectivity) of good condition Natural Habitat[7]. The Paracel long-term biodiversity monitoring programme (CSI Ingenieros) selectively confirms[8] such areas of both forest and non-forest Natural Habitat still exist in the landscape - for example seasonally inundated savannas with forest islands and a lack of invasive exotic species, or forests with intact canopies and good natural regeneration. A broader-scale survey undertaken in April 2022 to validate the remotely sensed vegetation mapping (randomised methods detailed in Appendix 1) provides a more representative picture of habitat condition across the landscape than the biodiversity monitoring programme plots. Validation results from the 77 plots sampled among the seven savanna formation classes show that the majority (77%) are either in a degraded or modified state[9]. This empirically confirms the general impression of observers that remaining savannas with natural character across the landscape are generally far more heavily degraded than the natural forest areas, with many patches either heavily infested with or dominated by alien invasive pasture grass species introduced for cattle grazing improvement purposes.

The main degrading forces for remaining natural areas have been grazing, burning, drainage and introduction of exotic grasses. Most conversion of natural cover has been for exotic pasture, with some cropping (mainly for animal feed) and historic experimental eucalypt plantations and an increasing trend in illegal crops. Without human perturbations, the fire ecology of the landscape would create a mosaic of patches in a constant state of flux with rapid post-fire regeneration of the savanna formations' woody cover component (sub shrubs, shrubs, and small trees).

[5] Including bird, plant, amphibian, and reptile species

[6] Landscape in this context means the Paracel properties and their surroundings – together comprising much of the Aquidabán ecoregion.

[7] Defined in PS6 (GN 2019) as areas where native species and natural vegetation structure still dominate.

[8] 23 of the 24 plots that the baseline & monitoring data collection is based upon were selected to represent good condition ('benchmark') examples of the range of natural habitat types present in the landscape (according to relatively undisturbed vegetation structure and species composition) (Prof. González Pers. Comm. May 2022) and so are not a representative sample.

[9] A meta-analysis by Prof González (comprising 66 of the 200 points – all those plots in savanna formations not identified through remote sensing as degraded) estimated that only 12% of were in a good condition (≥70% native cover, low grazing impact), 61% degraded (20-30% exotic species cover and intensively grazed) and 27% in a modified state (>70% exotic species cover and intensively grazed). Note, expert opinions vary about whether spread and domination by the exotic grass species is inevitable once introduced to an area, and if it is possible to restore areas once infested.

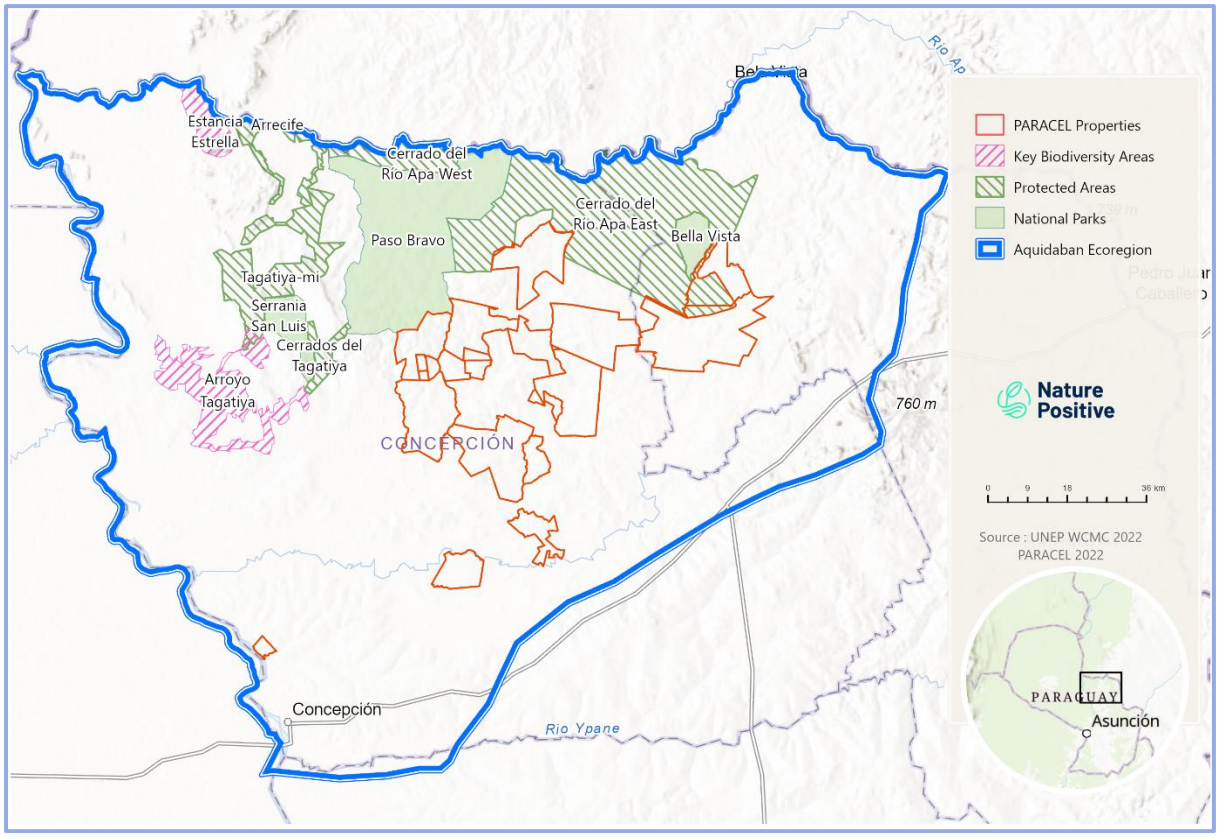

Figure 1: A map showing the Area of Analysis (the Aquidabán ecoregion) with location of Paracel properties, protected areas, and other areas of conservation interest (KBAs)

Several vegetation mapping field verification missions have confirmed that using accurate remote sensing spectral and radar data, it is impossible to accurately map the naturalness and condition of the savanna formations because the habitat patterns are small scale and the structural indicators used are driven by a confounding mix of natural (e.g., soil depth or wetness) and anthropogenic (e.g., grazing pressure, and unnatural fire frequency and intensity) factors.

Paracel will avoid all remaining forest areas larger than 1 ha and will restore 3000 ha of historic (pre-ownership) deforestation. Microplanning decisions on which areas of savanna formations are appropriate to plant or conserve will be made at the property and parcel level through the production of higher resolution (than with satellite imagery) mapping based on drone imagery, and ground verification to rapidly confirm the Critical Habitat status of questionable areas. Verification methods under development are based on presence and abundance of key native and exotic species, and potentially also the connectivity value between other patches of Natural Habitat. Using this method, each property to be planted will have an internally approved plan before planting proceeds which identifies Critical Habitat and other environmental constraints; these are referred to in the Environmental and Social Action Plan (ESAP) published by IDB[10] as 'estancia-specific Critical Habitat Assessments'. A microplanning lead has recently joined the Paracel team to take responsibility for this process.

[10] January 2022 version.

Purpose and Methods of this Assessment

Paracel is seeking funding from a consortium of lending institutions who require the projects they invest in to align with International Finance Corporation (IFC) 2012 Performance Standards (PS)[11]. This report is a Critical Habitat Assessment (CHA) for the Paracel project ('the Project') according to the latest Guidance Note (IFC, 2019) for Performance Standard 6 (PS6) on 'Biodiversity Conservation and Sustainable Management of Living Natural Resources'. It builds on the Critical Habitat (CH) screening work done as part of the Environmental and Social Impact Assessment submitted to the prospective lender group in October 2021. This report aims to:

1. Summarise the Critical Habitat Assessment results, determining why the Project area contains Critical Habitat (IFC PS6) by presenting the methods and results to justify which biodiversity features qualify or not
2. Evaluate the extent to which IFC PS6 has already been fulfilled (for the specific requirements when a Project operates in Critical Habitat (CH))
3. Indicate the feasibility of the with-project scenario achieving long-term Net Gain outcomes in the landscape compared to the no-project scenario
4. Provide recommendations to further mitigate impacts on biodiversity and fully align the Project with best practice (IFC PS6 and other stakeholder) expectations for biodiversity management

The term Critical Habitat (CH) refers to areas of the highest global or national biodiversity conservation importance for specific features. Its designation in a project's area of influence implies that extra focus must be placed on assessing the risk of significant impacts to high value biodiversity features and assuring their appropriate mitigation. A CHA is carried out at the landscape scale, using an ecologically and administratively appropriate Area of Analysis (AoA) that contains a Project's area of influence but is defined by biodiversity patterns rather than an evaluation of project impacts. It applies the conservation principles of ´vulnerability´ (threat) and ´irreplaceability´ (geographic rarity) to biodiversity at both global and national levels.

This CHA confirms the species or ecosystems which existing information either shows do or indicates might meet the criteria and quantitative thresholds (Tables Table Table Table) for designating the AoA as CH (IFC, 2019). The assessment is based on global datasets, published and unpublished literature, personal communications with recognized local and global species specialists[12], as well as the expert opinion of biodiversity specialists at Nature Positive and PARACEL's environmental team.

Implications of findings

Because CH has been determined with high confidence to be present in the project landscape, to ensure alignment with PS6 Paragraphs 17-19, and international good practice, the Project will need to demonstrate that:

1. No other viable alternatives exist for development of the project

[11] The Critical Habitat status and management options also have implications for compliance with VCS CCB certification (like with PS6 biodiversity Net Gain at the landscape scale is required) and FSC certification (avoidance of impacts to good condition areas of threatened ecosystems qualifying under HCV 3 standards).

[12] See acknowledgements

2. Existing information, and experts consulted, do not point towards the development of the Project resulting in a *net* reduction in the global and/or national populations of any Critically Endangered or Endangered species over a reasonable period
3. The project does not lead to measurable adverse impacts on those features for which the CH was designated, and on the ecological processes supporting those biodiversity values
4. A robust, appropriately designed, and long-term Biodiversity Monitoring and Evaluation Program (BMEP) is integrated into the client's management program.
5. In such cases where requirements 1-4 are met, the project's mitigation strategy will be described in a Biodiversity Action Plan (BAP) and designed to achieve Net Gains for those biodiversity features for which the Critical Habitat was designated.
6. In instances where biodiversity offsets are proposed as part of the mitigation strategy, the Project must demonstrate that its significant residual impacts on biodiversity will be adequately mitigated to meet requirements 2 & 3 above.

Compliance with the first two of these requirements has already been demonstrated[13] and the third can be determined with long-term monitoring data, provided the biodiversity monitoring protocols are revised[14] in line with this assessment and the Biodiversity Action Plan (BAP) to be developed. Therefore, **the main implication of the Critical Habitat determination is that the Project will need to demonstrate a 'Net Gain' for Natural Habitat versus the no-project scenario[15].**

High level ecological feasibility for Net Gain in the AoA has already been established with two potential corridor options identified. For forest habitats conservation gains will exceed losses through clearance of small (< 1 ha) forest island patches by many times because of the high rates of historic forest loss predicted to continue under a no-project scenario. If comprehensive conservation measures planned (including conservation of extensive and connected better condition Natural Habitat through set asides or offsets) are implemented, the species of concern and the key elements of the ecosystem should persist.

Because there are several species of stakeholder concern, (some of which may prove to qualify the area as CH with further data), it is good practice to include such taxon as priorities in the Project's BMEP, and to ensure benefits accrue from the BAP. These two documents should be integrated and iteratively updated to ensure an adaptive management approach so that mitigation and compensation measures can be demonstrated to result in Net Gain.

Net Gain Strategy

Paracel is currently undertaking detailed study, consultation, and planning activities to design its biodiversity Net Gain strategy in collaboration with international and national experts in ecology, biodiversity management and conservation. The fundamental approach is to follow the mitigation hierarchy and employ metrics accounting for habitat extent, condition, and conservation importance (inferred by connectivity) to monitor and demonstrate net gains.

[13] There are no viable alternatives to a project of this kind in the ecoregion, furthermore, given the pace and drivers of land use change currently operating in the region, the Paracel project offers a viable strategy to maintain the best conserved parts of natural habitat under private ownership the landscape. Based on 2 years of intensive biodiversity sampling in the landscape by the University of Asuncion / CSI Ingenieros team of ecologists, there is no evidence to suggest that any critical endangered or endangered species will be measurably impacted

[14] This will involve redesigning the monitoring programme to be more representative of the landscape and to specifically measure status of species of concern or conservation outcomes of mitigation measures.

[15] Interpreted as ensuring a representative and viable unit of natural habitat (with a range of savanna-forest physiognomies) is preserved, including lands adjacent to existing protected areas.

The first step in applying the mitigation hierarchy will be to avoid all areas of forest[16], wetlands and riparian margins, and avoid the highest conservation value examples of the natural savanna formations[17]. Further savanna formation areas will be avoided due to being inapt for planting owing to inadequate soils or size of patch for economic plantation establishment, maintenance, and harvesting. All avoided Natural Habitat will be conserved as set-asides. Minimisation measures include leaving buffers around natural habitat and wildlife rescue. Eucalyptus will be planted in remaining areas[18] which are a mixture of Modified Habitat (mostly exotic pasture and crops) and degraded Natural Habitat (natural savanna formations[19]) which may retain enough remnant biodiversity values to be counted as condition-adjusted 'losses' under the Net Gain accounting approach.

Historic clearance of forests since 2004 (from before Paracel's land acquisitions[20]) will be restored[21], summing to c. 3000 ha. Due to the removal or reduction in cattle grazing pressure from within Paracel's properties associated with forestry development, conserved areas of forest and savanna will benefit from avoided future degradation, and condition improvements will also accrue through passive regeneration.

Because of the large scale and geographical extent of the 20 Paracel properties (see Figure 2), the complexity of the ecology, and the establishment of plantations in 19 properties being spread over several years, the approach to applying the avoidance step of mitigation hierarchy will be progressive and operate at two different scales – i) landscape wide, and ii) property by property. The strategy is to attain a biodiversity Net Gain position through a combination of on-site restoration (for historic illegal deforestation) and averted-loss offsets (that, if necessary to achieve Net Gain, could include off-site areas in addition to the on-site set-asides).

[16] Forest is defined in accordance with UNFCCC and national legislative definitions to be patches of woody vegetation of more than 1 ha with a mean height of more than 5m and a canopy closure of 30% and above.

[17] These include a range of savanna formations with varying densities and types of trees, shrubs and sub-shrubs occurring within them.

[18] The area remaining for plantation establishment after all avoidance, minimisation and restoration measures are accounted for will be approximately 50% of the properties total area.

[19] This has already been verified by detailed biodiversity baseline studies across the properties led by national experts.

[20] The Land Conversion Moratorium for the Atlantic Forest of Paraguay, also known as the "Zero Deforestation Law" was passed in 2004. Paracel is restoring all known forest loss on its properties since the law was passed.

[21] Restoration techniques are yet to be trialled and will include a mixture of passive restoration relying on natural regeneration once degrading forces are removed, and active restoration.

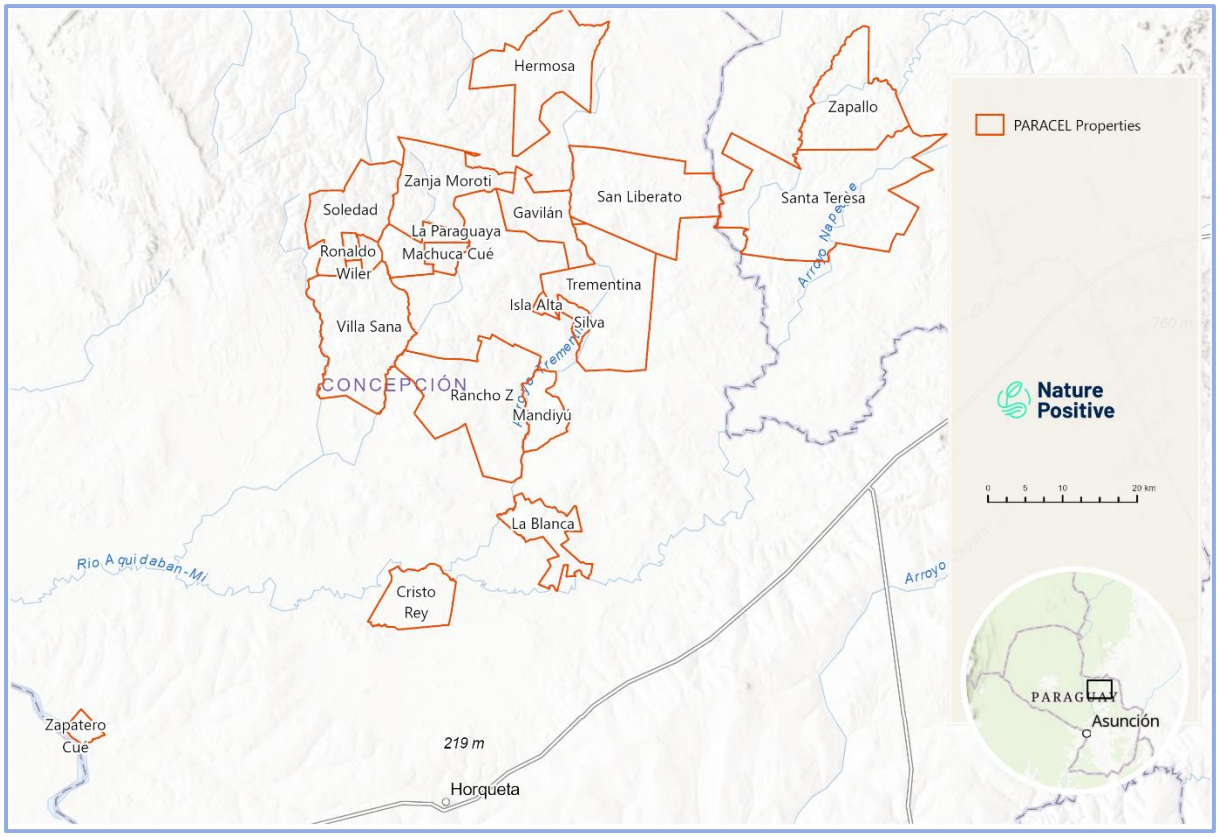

Figure 2: Paracel's 20 properties – the 19 properties clustered to the NE are for plantation development and Zapatero Cué in the SW is the Mill site.

The landscape scale strategic planning process includes production of a vegetation map (summary form presented in Figure 3) and a biomass baseline by vegetation type (presented in a separate study), with detailed ground validation collected from February 2022 to date (July 2022). This classification will be used as the basis for designing an approximate delineation of priority areas to avoid and conserve, with biodiversity accounting applied (using a Quality Hectares currency considering both area and condition per main habitat type) for the residual impacts accumulated by the projected land clearance in any areas with remnant natural values.

The landscape level mapping, accounting and scenario analysis being funded by Paracel will provide the Net Gain targets and feasible conservation approaches to attain these, including the priority areas of Natural Habitat to be set aside for conservation. This will provide confidence *a priori* that the likely sum of the property plantation developments is consistent with attaining a Net Gain outcome. Individual property 'micro-plans' developed at high resolution with the benefit of silvicultural and ecological field observations will map the final determination of plantation, conservation, and restoration zones. These micro-plans can be used to progressively[22] verify status against the landscape level residual impact and Net Gain predictions, with adaptive management being applied as necessary if attainment of Net Gain targets is in doubt.

[22] First time planting for the 7-year rotational harvesting will occur across the 19 properties until 2026.

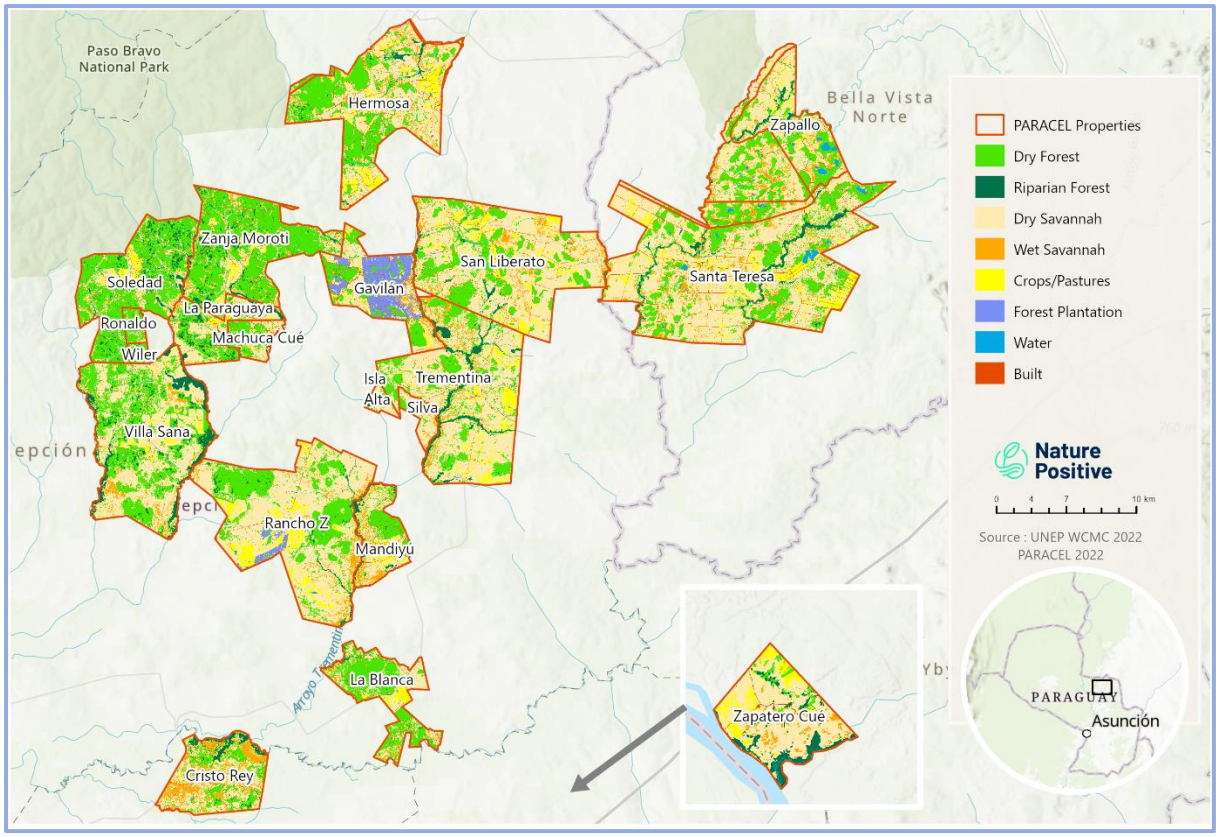

Figure 3: Simplified Land Cover map[23] based on 2022 validated landcover map (20 classes, Appendix 1)

Offset feasibility studies being planned will increase the accuracy of offset gain predictions so that the proportion of savanna-complex habitats cleared can be adaptively managed to assure Paracel remains on target to attain Net Gain. A study of 'additionality' is being undertaken to quantify the potential conservation gains that could be attained in different parts of the landscape[24] through averted-loss offsets. As a first step in the offset feasibility and planning process, national conservation experts are currently being consulted to estimate the proportion of projected future losses under the no-project scenario that could reasonably be expected to be avoided under different conservation strategies.

Several Key Biodiversity Areas (KBAs) and Protected Areas are present in the ecoregion. However, the land cover change analysis shows that protected status has not necessarily prevented habitat loss. Public protected areas have experienced high rates of habitat loss in recent years owing primarily to widespread illegal timber extraction and drug cultivation activity. Private protected areas existing in the region are being more effectively managed to prevent degradation. Substantial blocks of Natural Habitat on private land present in the landscape, including land owned by Paracel, present a conservation opportunity.

High level ecological feasibility for Net Gain has already been established, subject to confirmation from quantitative scenario modeling using a 'Quality Hectares' accounting approach, with two potential ecological corridor options providing connectivity at the ecoregional scale[25]. The core of these corridors

[23] Modified Habitat includes the crops/pastures, plantation forestry and built classes, plus a significant proportion of the dry savanna.

[24] Rates of habitat clearance in the AoA are not uniform and are strongly influenced by land tenure.

[25] These corridors would primarily link remaining areas of better condition Natural Habitat but there may be some fragments of Modified Habitat required to make biological corridors connecting important areas of Natural Habitat. This would allow for maintenance of metapopulations and provides passive or active restoration potential for Net Gain accounting purposes.

could be created by conservation zones incorporated within the plantation matrix of Paracel's properties. If necessary to assure a Net Gain at the landscape scale and to provide a nature positive legacy, Paracel will invest in biodiversity offsets beyond its property boundaries in the Aquidabán ecoregion to conserve one or several of the remaining high value habitat blocks.

In depth social, political, and economic feasibility analyses for Net Gain are planned to drive the production of a Biodiversity Action Plan detailing how Net Gain will be achieved and verified. Interviews of conservation leaders in Paraguay conducted by Nature Positive (May 2022) indicate that private property, and in particular estancias that have experienced continuous occupation and management presence can successfully be converted to conservation lands and adequate legal frameworks for private protected areas are available.

The next stage of the biodiversity work programme will be to combine the residual impact assessment, additionality assessment, and habitat mapping with the Net Gain feasibility analysis to provide spatially explicit scenarios for net-positive outcomes. Feasibility studies to determine the best conservation mechanisms, tenure, governance systems for the offset strategy will be completed in 2023 as an input to the Biodiversity Action Plan.

Recommendations and next steps

These are the main actions recommended for Paracel to operate in this landscape with Critical Habitat meeting the requirements for biodiversity Net Gain:

- The ESAP published by IDB in January 2022, and the more detailed version in the final ESDD report (ERM, 2022), contain PS6 requirements that are consistent with the future work required for Paracel to meet IFC Standards and should be adopted and implemented.
- Develop a Biodiversity Strategy to guide the Project's biodiversity management approach and act as a public facing document for investors, lenders, and other stakeholders.
- Implement plantation microplanning protocols to identify in the field the highest conservation value[26] (condition and connectivity) areas of savanna formations for protection.
- Given the CH designation applied by this report, a Biodiversity Action Plan (BAP) should be designed that can reasonably be expected to result in a Net Gain in Natural Habitat values, the maintenance of populations for any species of concern (e.g., globally threatened species or species of special stakeholder concern), and maintenance of any priority ecosystem services identified by the Ecosystem Services Review planned in the ESAP.
- The BAP should be developed as the overarching document that explains all the biodiversity management measures including avoidance, minimisation, restoration, and offsets (on-site set-aside or otherwise). The BAP will signpost to, but not give detail of, all the management plans, of which the Biodiversity Offset Management Plan will be one.
- Establish a small biodiversity working group (with Paracel staff and external support) to ensure adequate stakeholder[27] input to development of the BAP. Invest time in developing the optimal landscape conservation vision for the Paracel Properties in connection with the neighbouring properties, including consulting with other private landowners who may hold blocks of land with high landscape connectivity value or a significant extent of good condition savanna formations.

[26] This would also serve to identify HCV areas for FSC certification.

[27] E.g., national conservation leaders and key local representation such as affected indigenous communities.

- Areas that were degraded before Paracel's land acquisitions and are not required for plantations present an opportunity to be actively, and/or passively restored; these areas, especially if providing connectivity to other high value zones would make especially large contributions to biodiversity net gain.
- Undertake detailed feasibility assessments for the biodiversity offset candidate sites (including set asides and offsets in adjacent properties) and management options, considering ecological, social, political, technical, cultural, and economic factors.
- Design a supporting Biodiversity Monitoring and Evaluation Program to demonstrate species of concern retain good populations and where Paracel's position relative to Net Gain stands over time. Use the BMEP to adaptively manage the BAP to achieve goals in the most time and cost-effective manner.
- Because of the importance of demonstrating a Net Gain for biodiversity to the lenders and carbon markets, publicly commit to be a 'nature positive' company: to account for all adverse impacts on priority biodiversity and nature's benefits to people and create a Net Gain in natural values at the landscape level.
- Develop a biodiversity management team within Paracel. At minimum, by the end of 2022 a 'biodiversity manager' will be required whose responsibility it is to work with consultants, collaborators and internally to develop the BAP and associated Management Plans. By 2025 the BAP should be in full implementation phase and 3-5 people (including field and office presence) would be required, depending on the level of delegation to third party conservation management parties.

2. Project Description

The Paracel Project ('the Project') is a large forestry and industrial project located in the Departments of Concepción and Amambay, within the Paraguay established by Copetrol (Paraguay) and Girindus Investments (Sweden). It will be the largest private investment in Paraguay's history, involving the largest foreign direct investment.

The Project's industrial component is a pulp mill with a capacity of 1.5 million tons per year of bleached pulp for paper. In the long term, the wood for the mill will be sourced from c. 90,000 ha of eucalyptus trees grown on a seven-year rotational cycle within 19 properties owned by the company (see Figure 2), and c.100,000 ha from a series of 'Outgrowers' – private landowners in the region whom Paracel will contract to supply wood.

Until regional supply from Paracel and its Outgrowers peaks, wood volumes up to the capacity of the mill will be supplemented from other sources in Brazil, Argentina and elsewhere in Paraguay, certified with the Forest Stewardship Council (FSC) 'MIX' label. The wood will be transported either by river to "Puerto PARACEL", located adjacent to the mill in the Zapatero Cué property, next to the city of Concepción, or by road from the Paracel or Outgrower properties to the same site. It is expected that the construction phase of the mill will be completed in 2023, with operations commencing in 2024.

Paracel's properties have a total area of approximately 190,000 ha. Subject to further studies and micro-scale planning, c. 50% of this land will be planted, and the remaining amount conserved (representing most of the less degraded habitat existing within the properties) or restored (c. 3000 ha).

The Project will market carbon credits through its exotic afforestation, native forest restoration and native habitats conservation activities. Consistent with its commitment to reduce GHG emissions, Paracel will construct a 220 MW renewable energy power plant fired by biomass (wood waste and wood liquor) to supply 120 MW to the mill and export the surplus 100 MW to the Paraguayan grid.

The Paracel leadership understands the company is operating in a high biodiversity transitional Cerrado ecosystem of global and national conservation importance. Paracel is committed to global best practice for the environmental and social outcomes of its operations. It is applying the International Finance Corporation Performance Standards to all components of the project. It has established eligibility for certification under Verra's VCS Standard for carbon credits and is entered the validation process in May 2022. It plans to attain FSC certification for its cellulose product. Furthermore, it is adopting the public position of being committed to generating a net positive outcome for biodiversity.

3. Methods

Summary

A comprehensive review of available Project and scientific literature on the ecology and biodiversity of the area was performed, experts were consulted, and the Area of Analysis (AoA) for the CHA was determined as the Ecoregion of Aquidabán (SEAM, 2013). An initial screening of species against CH criteria was based on the Integrated Biodiversity Assessment Tool (IBAT) data with existing published and unpublished documentation, Paracel baseline surveys, and the interpretation of global and regional datasets (including the IUCN Red List of Threatened Species, Ministerio del Ambiente y Desarrollo Sostenible (MADES) national list of threatened species, and the Global Biodiversity Information Facility (GBIF)). Where information was incomplete, or not available, local and international experts were consulted. Vegetation maps using satellite imagery and ground truthing, provided some guidance on the scale of natural habitats existing in the area with which to corroborate species records and likely distributions. Lastly, PS6 criteria and thresholds were applied.

Identifying an appropriate Area of Analysis

A CHA is carried out at the landscape scale using an AoA that considers large-scale ecological patterns and administrative boundaries rather than the location of potential project impacts. The boundary of an AoA will extend beyond a project's footprint, and often its area of influence too. An ecologically appropriate Area of Analysis (AoA) should cover the extent of the ecosystem required to support the long-term persistence of the species, communities and habitats which occur in the project's direct or indirect area of influence.

The area where PARACEL will operate is in a unique ecosystem representing the southern tip of the Cerrado biome and the largest extent of Cerrado in the country of Paraguay. It is a transitional zone between the Humid Chaco biome to the west and the Atlantic Forest biome to the east. This large-scale ecological transition is reflected in the climatic gradient of increasing dryness toward the centre of the continent and into the Chaco dry ecosystems. After several consultations with local, and international experts, the AoA was selected to be the Aquidabán, ecoregion[28] which encompasses the total extent of the Cerrado ecosystem in this region and covers 10,700 km^2 (1,070,000 ha) see Figure 1). The Paracel properties comprise c. 18% of the ecoregion's area and are well spread across it.

CH criteria & thresholds assessment

The Integrated Biodiversity Assessment Tool (IBAT) spatial data provided 980 records of species known to be present in the Area of Analysis. Additional information on species present in the area was obtained from the Environmental and Social Impact Assessment (ESIA), and from grey literature. Local and international species specialists were consulted.

Likely population sizes, trends, and geographical distribution were assessed with the IUCN and GBIF databases and expert consultation for all globally threatened (IUCN CR, EN and VU categories) and nationally highly threatened species (Especies Amenazadas de Extinción, and Especies en Peligro de Extinción published by the Secretaría del Ambiente (SEAM) de Paraguay).

A screening was performed to determine whether any of the five core CH criteria (Table 1) would qualify the AoA as containing Critical Habitat according to IFC thresholds and guidance. All criteria have equal importance.

[28] from the official Paraguayan Ecoregions established by the Resolution SEAM No. 614/2013

Table 1. PS6 Critical Habitat criteria thresholds and descriptions

Criterion	Thresholds & Description
Criterion 1-CR and EN species	1a. Areas that support globally important concentrations of a CR or EN species/subspecies (≥ 0.5 %of the global population AND ≥ 5 reproductive units(a) of a CR or EN species/subspecies.
	1b. Areas that support globally important concentrations of a VU species, the loss of which would result in up listing to CR or EN and meeting the threshold above.
	1.c As appropriate, areas containing important concentrations of a nationally or regionally listed CR or EN species
Criterion 2-Endemic or restricted-range species	Areas that regularly hold ≥ 10 %of the global population size AND ≥ 10 reproductive units(a) of a species.
Criterion 3-Migratory and/or congregatory species	3a. Areas known to sustain, on a cyclical or otherwise regular basis, ≥ 1% of the global population of a migratory or congregatory species at any point of the species' lifecycle.
	3b. Areas that predictably support ≥ 10 %of the global population of a species during periods of environmental stress.
Criterion 4-Highly threatened and or unique ecosystems	4a. Areas representing ≥ 5 %of the global extent of an ecosystem type meeting the criteria for IUCN status of CR or EN.
	4b. Other areas not yet assessed by IUCN but determined to be of high priority for conservation by regional or national systematic conservation planning.
Criterion 5-Evolutionary processes	The evolutionary processes that drive speciation and result in both genetic diversity and endemism are important to maintain as are conserving the landscape scale features that drive those processes. These can include isolated areas such as islands, heterogeneous landscapes, and sites of demonstrated importance for climate change adaptation. Subpopulations of a species with a unique evolutionary history may also be indicative of key evolutionary processes.

In this assessment CH qualification is evaluated using a scale of probability with five categories:

- **Qualifying:** Sufficient evidence that:
    - The feature is confirmed present in the AoA (through ESIA, IUCN, GBIF, IBAT and published and grey literature searches), AND
    - The feature likely triggers the CH threshold (at levels that meet/approach the threshold) based on the distribution data as a proxy for population estimate (when population data is not available)
- **Likely:** There is reasonable evidence that
    - The biodiversity feature is present in the AoA, AND
    - At levels that meet/approach the threshold

- **Possible:**
    - Low evidence that the feature is present in the AoA but if confirmed likely to meet the threshold, OR
    - Good evidence that the feature is present in the AoA but unclear if it would meet the threshold
- **Unlikely:**
    - Reasonable evidence that the species does not meet the threshold
- **Not qualifying:**
    - Available information is clear enough to state that the species will not meet any of the thresholds for CH

Constraints and limitations of this CHA

This CHA was conducted using the best available information at the time of this assessment (July 2022). This includes IBAT, IUCN Red List, GBIF, eBird, KBA, BirdLife International, MADES, published studies, grey literature, and Paracel commissioned reports (CSI Ingenieros, 2021; Poyry, 2021; Yanosky, 2020), as well as opinions from species-group experts. However, the Project is in an area that all experts consulted acknowledge has been poorly studied historically (for example, only two groups of botanists having worked in the area before the Paracel baseline study). Therefore, it is likely that further species will be found to be present, and others will be found to be present in different abundances or distributions than initially thought and such new information may alter the criteria and species for which CH is designated.

Because the presence of CH in the landscape is designated by the ecosystem being threatened, the location of areas of CH is determined by the condition of Natural Habitats. However, because of the complexity of natural habitat types and the rapid degradation experienced in the past decades it has not been possible to reliably map remaining non-forest Natural Habitats using remote sensing so precise location of these will require ground-truthing as part of the plantation microplanning process.

Outgrower locations are likely to be concentrated in the AoA but are currently unknown, so this CHA does not necessarily apply to the footprint of that supply chain component of the project.

4. Results Summary

Based on the best available information there are no species which qualify the area as Critical Habitat, whereas 15 species are likely to and a further 29 may possibly qualify (summary results in Tables 2, 3, and 4; justifications for CH qualification probability classes in Table 7). These species can be termed 'species of concern'. Further information on distribution and abundance of species of concern may potentially increase the AoA's importance for these species and so confirm some of them as CH-qualifying features.

The following three subsections list the species that could possibly or might likely qualify the AoA as a Critical Habitat under Criteria 1, 2 and 3 respectively. Species that are either globally threatened or nationally[29] endangered[30] are included. A precautionary approach would include targeted acquisition of further information on these species of concern from the Paracel biodiversity monitoring program to better determine their status. Confirmation of presence of these species in any part of the landscape may not imply any potential adverse impacts on the part of the project (for example for forest dependent bird species whose habitat is preserved by default). It could inform specific conservation management measures of the planned protection and restoration areas to enhance the populations of these species.

Criterion 1: Critically Endangered (CR) and/or Endangered (EN) species

Criterion 1a relates to areas that support globally important concentrations of a CR or EN species/subspecies. Under this sub-criterion no species were found to be qualifying and six species were found to possibly qualify the AoA as containing Critical Habitat (Table).

Table 2. Species that possibly qualify the AoA as Critical Habitat under Criterion 1a.

Criterion 1a				
Taxon	**Common name**	**IUCN status**	**National list**	**Category**
Plants				
Discocactus hartmannii	-	**CR**	**EP**	Possible
Fish				
Hyphessobrycon wajat	-	**DD**	-	Possible
Reptiles				
Phalotris nigrilatus	-	**EN**	**EP**	Possible
Birds				
Amazona vinacea	Vinaceous-breasted amazon	**EN**	**EP**	Possible
Harpyhaliaetus coronatus	Crowned solitary eagle	**EN**	**AE**	Possible
Sporophila palustris	Marsh seedeater	**EN**	**EP**	Possible

Note: DD- Data Deficient, EN- Endangered, CR- Critically endangered, EP- Especies en peligro de extinción, AE- Amenazada de Extinción (MADES Res 26).

[29] MADES Resolutions 254/19, 433/19, 470/19, and 206/20 were consulted to assess nationally threatened species status.

[30] We have been unable to confirm directly with the Paraguayan authorities if the national threatened species lists were drafted using IUCN Guidelines for Application of Red List Criteria at Regional and National Levels as per IFC guidance (https://www.iucnredlist.org/resources/regionalguidelines). We understand they were not, nevertheless we judge them to have validity as the official Paraguayan determination.

Criterion 1b focuses on areas that support globally important concentrations of a VU species, the loss of which would result in up listing to CR or EN. No species were found to possibly, or likely qualify the AoA as Critical Habitat under Criterion 1b.

Criterion 1c, which assesses the areas containing important concentrations of a nationally or regionally listed CR or EN species, was the Criterion that produced the most extensive list of species[31] that likely, or possibly qualifies the AoA as Critical Habitat (Table).

Table 3. Species that likely, or possibly qualify the AoA as Critical Habitat under Criterion 1c.

Criterion 1c				
Taxon	**Common name**	**IUCN status**	**National list**	**Category**
Plants				
Bactris glaucescens	-	**-**	**EP**	Likely
Gymnocalycium anisitsii	-	**LC**	**AE**	Likely
Myroxylon peruiferum	Quina	**LC**	**EP**	Likely
Syagrus oleracea	Guariroba	**-**	**EP**	Likely
Amburana cearensis	-	**EN**	**EP**	Possible
Balfourodendron riedelianum	-	**EN**	**EP**	Possible
Dimorphandra mollis	-	**LC**	**EP**	Possible
Discocactus hartmannii	-	**CR**	**EP**	Possible
Frailea schilinzkyana	-	**VU**	**EP**	Possible
Trichilia stellato-tomentosa	-	**LC**	**EP**	Possible
Amphibians				
Dendropsophus elianeae	-	**LC**	**EP**	Possible
Reptiles				
Bachia bresslaui	Bresslau's bachia	**VU**	**-**	Likely
Eunectes murinus	Green anaconda	**LC**	**AE**	Likely
Salvator duseni	Yellow tegu	**LC**	**EP**	Likely
Chelonoidis carbonaria	Red-footed tortoise	**-**	**EP**	Possible
Norops meridionalis	-	**-**	**EP**	Possible
Phalotris nigrilatus	-	**EN**	**EP**	Possible
Birds				
Alipiopsitta xanthops	Yellow-faced parrot	**NT**	**AE**	Likely
Anodorhynchus hyacinthinus	Hyacinth macaw	**VU**	**EP**	Likely
Ara ararauna	Blue-and-yellow macaw	**LC**	**EP**	Likely
Ara chloropterus	Red-and-green macaw	**LC**	**EP**	Likely
Cyanocorax cristatellus	Curl-crested jay	**LC**	**AE**	Likely
Alectrurus tricolor	Cock-tailed tyrant	**VU**	**EP**	Possible
Amazona vinacea	Vinaceous-breasted amazon	**EN**	**EP**	Possible
Laterallus xenopterus	Rufous-faced crake	**VU**	**AE**	Possible

[31] The reptile *Bachia bresslaui* and the bat *Natalus stramineus* are not nationally listed. However, they are included because local experts stated that those two species are rare, and more information is required (see Appendix 2).

Sporophila palustris	Marsh seedeater	**EN**	**EP**	Possible
Mammals				
Ozotoceros bezoarticus	Pampas deer	**NT**	**EP**	Likely
Natalus stramineus	Mexican funnel-eared bat	**LC**	**-**	Possible
Priodontes maximus	Giant armadillo	**VU**	**EP**	Possible
Pteronura brasiliensis	Giant otter	**EN**	**EP**	Possible

Note: DD- Data Deficient, NT- Near Threatened, VU- Vulnerable, EN- Endangered, CR- Critically endangered: AE- Amenazada de Extinción, EP- Especies en peligro de extinción (MADES Res 26).

Criterion 2: Endemic or restricted-range species

There were no species that qualify the AoA as CH under Criterion 2. Nevertheless, seven species were found to possibly do so, and one species to likely do so (Table).

Further information on the presence, and distribution of the populations of these species would be required to decrease the level of uncertainty.

Table 4. Species that likely, or possibly qualify the AoA as Critical Habitat under Criterion 2.

Criterion 2				
Taxon	**Common name**	**IUCN status**	**National list**	**Category**
Plants				
Opuntia stenarthra	-	**DD**	-	Possible
Trichocereus hahnianus	-	**DD**	-	Possible
Insects				
Ateuchus contractus	-	**DD**	-	Possible
Progomphus flinti	-	**DD**	-	Possible
Amphibians				
Rhinella scitula	-	**DD**	**AE**	Possible
Reptiles				
Amphisbaena albocingulata	-	**LC**	-	Likely
Phalotris nigrilatus	-	**EN**	**EP**	Possible

Note: DD- Data Deficient, LC Least Concern, EN- Endangered. AE- Amenazada de Extinción, EP- Especies en peligro de extinción (MADES Res 26).

Criterion 3: Migratory or congregatory species

The information available on the migratory species shows that none of the 241 species shown by IBAT in the AoA that are nomadic, altitudinal migrants, or full migrants, would qualify the AoA as CH.

Bats

Analysis of the IBAT database for the AoA returned three species of fully migrant bats. In addition, the Mexican greater funnel-eared bat (*Natalus stramineus*) is one of the rarest bats in Paraguay and is associated to caves. The southernmost site where there are records of this bat being present is in Concepción, with most reports corresponding to Mexico and the Caribbean. There is no evidence that supports that the AoA sustains more than 1% of the global population of a migratory or congregatory bat species at any point of the species' lifecycle.

Birds

Analysis of the IBAT database for the AoA show four species of birds that are altitudinal migrants, four nomadic, and 229 full migrant birds, but none of them triggered CH under Criterion 3.

Fish

Neither of the two fish species recorded as present in the area by IBAT qualify the AoA as Critical Habitat under Criterion 3. The ESIA additionally reports one vulnerable species *Potamorrhaphis eigenmanni*, for which GBIF shows a broad distributional range across Paraguay, Bolivia, and Brazil. Therefore, it is concluded that the AoA does not sustain on a cyclical or otherwise regular basis more than 1% of the global population of any migratory or congregatory fish species.

Insects

Records of four fully migrant insects were shown by IBAT for the AoA, none of them triggering CH.

Criterion 4: Highly threatened and/or unique ecosystems

Threatened ecosystems or ecosystems that host unique assemblages, may trigger CH under Criterion 4. Criterion 4a gives quantitative thresholds but requires an IUCN Red List of Ecosystems assessment to apply these and none currently exists for Paraguay[32]. Criterion 4b[33], supporting GN6 guidance[34], and verbal confirmation[35] indicate the appropriate approach in this case is to screen against the five IUCN RLE Criteria (Bland et al., 2015) with the data available.

There is insufficient information to apply IUCN RLE Criteria B, C and D and E. However, analysis of satellite imagery available between 1985 and 2021 provides the opportunity to apply Criterion A1 which assesses the decline in geographic distribution in the past 50 years, assigning the following threatened categories according to the percentage loss of habitat area:

- CR ≥80%
- EN ≥50%
- VU ≥30%

Analyses of three historical points in time[36] (see Appendix 3) show a total of 28% of natural habitat extent within the AoA was lost in the 36 years between 1985 and 2021. A linear extrapolation of this averaged figure, to the past 50 years would give an estimation of a decline of 39% for that period. Therefore, applying the IUCN categories the Cerrados de Concepción can be confidently classed as a (Vulnerable) Threatened Ecosystem, even considering sources of uncertainty in the estimation of loss rates. Note that a full assessment of any applicable IUCN Red List Criteria by an IUCN approved panel would be required to make an official decision on status.

[32] Experts consulted on this matter (including A. Yanosky, 2022) reported that several workshops were organised in 2017 to start the process, but no full assessments have been made up to date.
[33] Criterion 4b states that ecosystems 'not yet assessed by IUCN, but determined to be of high priority for conservation by regional or national systematic conservation planning' could qualify as CH.
[34] 'Where formal IUCN assessments have not been performed the client may use assessments using systematic methods at the national/ regional level, carried out by governmental bodies, recognized academic institutions and/or other relevant qualified organizations'
[35] IFC will not normally expect a client to conduct their own IUCN RLE assessment but encourages clients to do so where it helps clarify risks, Lori Conzo Pers. Comm 2017.
[36] With an average classification accuracy of 78% (See Appendix 3 for accuracy figures per dataset used), reflecting the limited resolution of the older 1980s data and thus comparability of the satellite imagery over the time frame since then. The analysis was corroborated with Global Forest Watch data.

The classification of the Cerrados de Concepción ecosystem as Threatened should be treated in context of threat assessments for the Cerrado biome as a whole. The Cerrado biome is one of the world's largest and biodiverse savanna regions, and is considered a biodiversity hotspot (Mittermeier et al., 2004). Many species are endemic to the Cerrado, and this biome supports unique ecosystems within it. These species and ecosystems are highly vulnerable to anthropogenic impacts (de Queiroz et al., 2020), such as fires, and clearing for farming, development, agriculture, or logging. More than 50% of the original habitat cover has been lost between since the 1970s, and 82% of the original area is predicted to be gone by 2050 (CEPF, 2017; Klink & Machado, 2005; Machado, 2015; Machado et al., 2004). Habitat conversion in the biome has been mostly caused by the expansion and intensification of agriculture and forestry.

The pattern of accelerated land-use change seen in the Brazilian Cerrado, now extends into Paraguay. Eastern Paraguay has recently attracted a strong flow of foreign investment, in part because land in Brazil has become more expensive and because of emerging state and federal environmental restrictions in Brazil. Global Forest Watch data for forest loss and soy expansion shows that conversion of natural habitats has been most pronounced to the east and south of the AoA.

Criterion 5: Key evolutionary processes

All experts consulted alluded to the complexity of the plant assemblages, microhabitats, and gradients of the transitional ecosystems within the AoA. The general view that the confluence of three biomes makes up the AoA (Chaco, Cerrado and Atlantic Forest), is borne out by the highly heterogeneous and ecotonal landscape. Several authors have associated ecotones with higher genetic diversity. Therefore, it is possible that the AoA hosts key evolutionary processes for some species groups.

Species of national interest or stakeholder concern

None of the experts consulted mentioned species of stakeholder concern, apart from those species that are nationally threatened (listed as Amenazadas de Extinción, or En Peligro de Extinción by MADES). Further information is required in this regard to understand the importance of certain species to local stakeholders for cultural, medicinal, nutritional, social, or cultural purposes. The draft Environmental and Social Action Plan requires a full Ecosystem Services Review (PS6) to be conducted and to consolidate the Project's various Indigenous Peoples Plans (PS7); these supplementary studies should confirm any dependence of local Indigenous communities upon species for economic or cultural reasons.

Protected areas and internationally recognised areas

The Area of Analysis (AoA) includes all or part of the public and private protected areas and KBAs listed below. Some of the KBAs' areas are legally protected.

Public protected areas:

Public protected areas present in the AoA include: Bella Vista National Park, Caberna Kamba Hopo, Cerrados del Rio Apa Biosphere Reserve, Cerro morado Caverna Ycua Pai, Cerro Tres Cerros-Cavernas 14 de Julio y Santa Caverna, Estero Milagro, Paso Bravo National Park, Santa Elena, and Serrania San Luis National Park.

Some of the Paracel properties are adjacent to public protected areas, and two overlap with part of the non-core[37] zone of the Cerrados del Rio Apa Biosphere Reserve. The Project is implementing a 1 km buffer between plantations and the two National Parks (Bella Vista and Paso Bravo) adjacent with parts

[37] The core areas are represented by Paso Bravo and Bella Vista National Parks, although no current management plan exists for the Biosphere Reserve as an entity, or has ever existed.

of its estate. In the overlap[38] with the Biosphere Reserve, Paracel has committed[39] to ensure that 50% of the area will remain under natural cover. Technically, any overlap with the Biosphere Reserve would trigger CH requirements, however this area's importance is diminished because consultations with conservation leaders in Paraguay, including MADES and SENAD senior staff, indicate that the Biosphere Reserve was initiated by Decree, had insufficient local consultation, has no management plan, and suffers from high rates of land conversion for illegal crops[40].

Private protected areas:

There are many private protected areas in the AoA which have been created mainly from retiring parts of large cattle ranches and which enjoy a relatively high level of protection compared to public protected areas. They include: Arrecife, Arroyo Blanco, Cerrados del Tagatiya, Estrella, Guayacan I II III, and Tagatiya-mi. The Project is not adjacent to any private protected areas.

Key Biodiversity Areas (KBAs):

Several KBAs have been identified in the AoA including Estancia Estrella, Arroyo Tagatiya, Cerrados de Concepción, and Arroyo Blanco. Arroyo Blanco and Cerrados de Concepción have reasonably high levels of legal protection whereas Arroyo Tagtiya has little and Estancia Estrella has none. The Project overlaps and is adjacent to parts of the Cerrados de Concepción KBA through the public protected areas mentioned above.

Arroyo Blanco

Located in the north-east of the AoA, Arroyo Blanco covers an area of 7,713ha, was assessed in 2007 as a KBA, before it was assessed as an IBA in 2011. This KBA, of which 71% is a Protected Area, is located in between Atlantic Forest and Cerrado, presenting an area of transition in between, and contains dense, and semideciduous forests that reach heights of up to 25m. The main threats to Arroyo Blanco's ecosystems are logging and wood harvesting, as well as invasive species.

Arroyo Tagatiya

Arroyo Tagatiya was assessed as a KBA in 2016, and as an IBA in 2011. The KBA covers a total of 30,739ha, of which 7% is a Protected Area by Guayacan I II III and Tagatiya-mi. Arroyo Tagatiya is home to some globally threatened species such as *Harpyhaliaetus coronatus, Anodorhynchus hyacinthinus, Culicivora caudata, Alectrurus tricolor y Procnias nudicollis*. Conversion of Campos to pasture, deforestation, hunting, anthropogenic fires, invasive species, limestone extraction, roads and unsustainable tourism are the biggest threats to Arroyo Tagatiya.

Cerrados de Concepción

With 135,813ha, was first assessed as an IBA in 2011 and then as KBA in 2016, 90% overlaps with the Protected Areas of Arrecife, Cerrados del Rio Apa Biosphere Reserve, Cerrados del Tagatiya, Paso Bravo, Serrania San Luis and Tagatiya-mi. Cerrados de Concepción is an area with Cerradones, riparian forests, forests, Campos and with large areas dedicated to pastures. Deforestation, hunting, grazing, anthropogenic fires, and invasive species such as the African jaraguá (*Hyparrhenia rufa*) are the main threat. Illegal logging is constantly reported in the area. Other threats include the construction of roads.

[38] Including the 1 km buffer from Bella Vista National Park in which no plantation will be established. All overlap is with the buffer zone - no overlap exists with the core areas (the National Parks).
[39] In compliance with Article 31 of SEAM Resolution No. 200/01.
[40] Confirmed by the land use change analysis undertaken for assessing Criterion 4.

Estancia Estrella

Located in the north-western area of the AoA, and bordering Brazil, Estancia Estrella was assessed as an IBA in 2011 and as KBA in 2016, and is non-protected KBA of 11,015ha. Hunting and collecting terrestrial animals are a threat in Estancia Estrella, which is causing or likely to cause very rapid declines of more than 30% over 10 years, or three generations, whichever is the longer. Other threats are anthropogenic fires, and the use of invasive species such as the African jaraguá (*Hyparrhenia rufa*) for grazing.

Ramsar sites:

There are no Ramsar sites within the AoA, with the closest being the Parque Nacional Estero Milagro, downstream of the Project and 60 km south of the city of Concepción. Estero Milagro, characterized by natural grasslands, low forests, wooded savannas and gallery forest, swamps, small marshes, and a great diversity of plant species, provides c.25,000 ha of excellent habitats for wildlife, and is one of the most important aquatic environments in Paraguay, important for several endangered species, migratory birds and five threatened plant species.

Natural and Modified Habitat identification

Performance Standard Guidance

PS6 (IFC, 2019) defines a 'habitat' as a terrestrial, freshwater, or marine geographical unit or airway that supports assemblages of living organisms and their interactions with the non-living environment. Critical Habitats are a subset of modified or natural habitats.

Natural Habitats are considered as areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition. Selectively logged forests for example, usually retain most of the original species and ecological processes and so would in most cases still be considered Natural Habitat.

Modified Habitats are considered as areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Monoculture forestry plantations, arable fields and urban areas show "substantial modification" and would be classed as Modified.

Natural and modified habitats therefore are perceived to exist on a continuum that ranges from largely undegraded natural habitats to intensively managed, modified habitats (IFC, 2019). Both Natural and Modified habitats may contain high biodiversity values, thereby qualifying as Critical Habitat.

Interpretation in the Paracel landscape

The Cerrado ecosystem present in this landscape includes a high diversity of natural habitat types that are distinguishable by their vegetation structure and species composition. Detailed descriptions of each vegetation class can be found in the biodiversity monitoring reports commissioned by Paracel.

In the field, the level of modification of the Cerrados de Concepción ecosystem habitats can be indicated by alterations in the vegetation structure, reduction in native species dominance or the presence of exotic species.

Most of the Project site displays a range of modification extent based on the cumulative intensity of historic grazing, burning and pasture improvement practices associated with cattle ranching. Most non-forest areas with remnant natural habitat features (e.g., forest islands) are now found in a degraded state, and an increasing and significant minority of these non-forest areas have been converted completely to modified exotic pasture, crops, and forestry plantations.

Areas that have undergone the most intensive human alteration including most obviously those areas that have been entirely converted to exotic pasture with African grasses, to croplands, forestry, or various built environments, are treated as *de facto* Modified Habitat. There are areas not entirely converted but considered Modified Habitat because their state of degradation is considered severe enough that regeneration back to a natural ecosystem would be unlikely to occur (e.g., where erosion is advanced and/or exotic grasses are becoming well established).

There remains a significant minority of land cover which is in relatively good natural condition and retains reasonable connectivity – this is interpreted as Natural Habitat. In this AoA it is likely that only Natural Habitats, in their natural mosaic formation, would support significant permanent populations of the biodiversity values that have been screened to potentially qualify the area as Critical Habitat.

5. References

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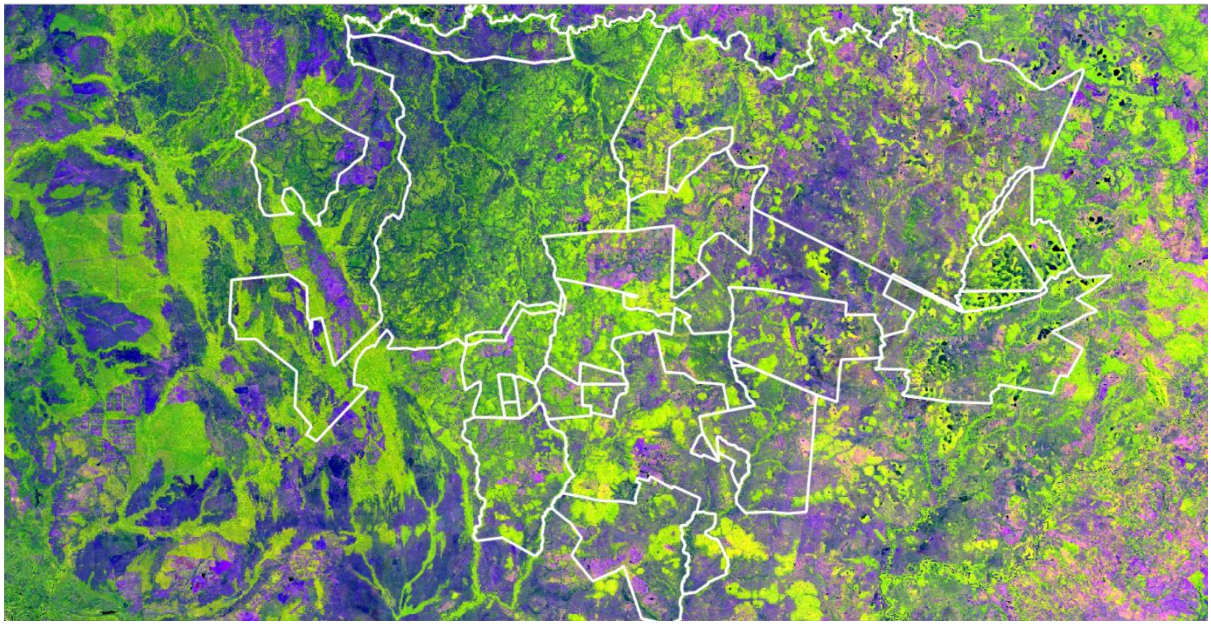
Appendix 1: Vegetation mapping and ground verification techniques

Vegetation mapping

Vegetation/Habitat condition mapping of the Area of Analysis (the entire Aquidabán ecoregion) was carried out for the purpose of deriving a baseline (2019) mapping of habitat type with the identification of natural versus modified habitat where possible. This was done in conjunction with the biomass assessment for the same region for carbon stock measurements (separate analysis presented elsewhere for carbon credit validation).

General interpretation of the Sentinel-2 optical Remote sensing images used in the classification

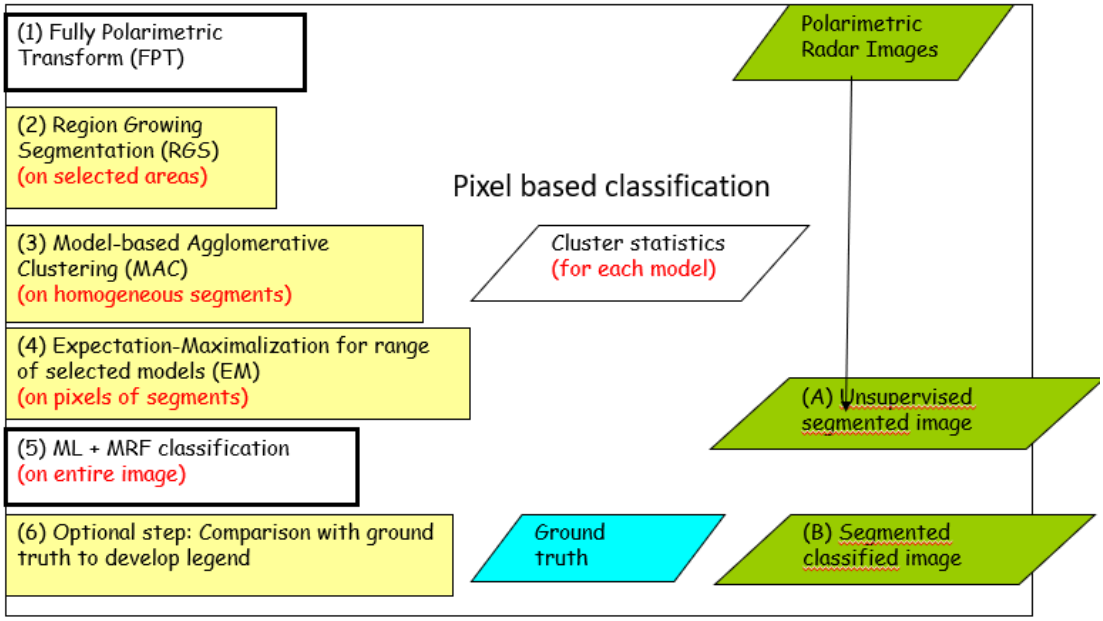
The high-resolution optical image is a colour composite of the Sentinel -2 optical images and shows the optical bands used for the classifications: R: PC-1; G: NDVI and B: PC-2. In this composite the bright green areas correspond to areas with dense vegetation while the light and dark green areas correspond to the Cerrado vegetation, and the bluish areas correspond to areas of savannas and Campos. Areas with Dark blue correspond to areas that were flooded during the acquisition of the images.

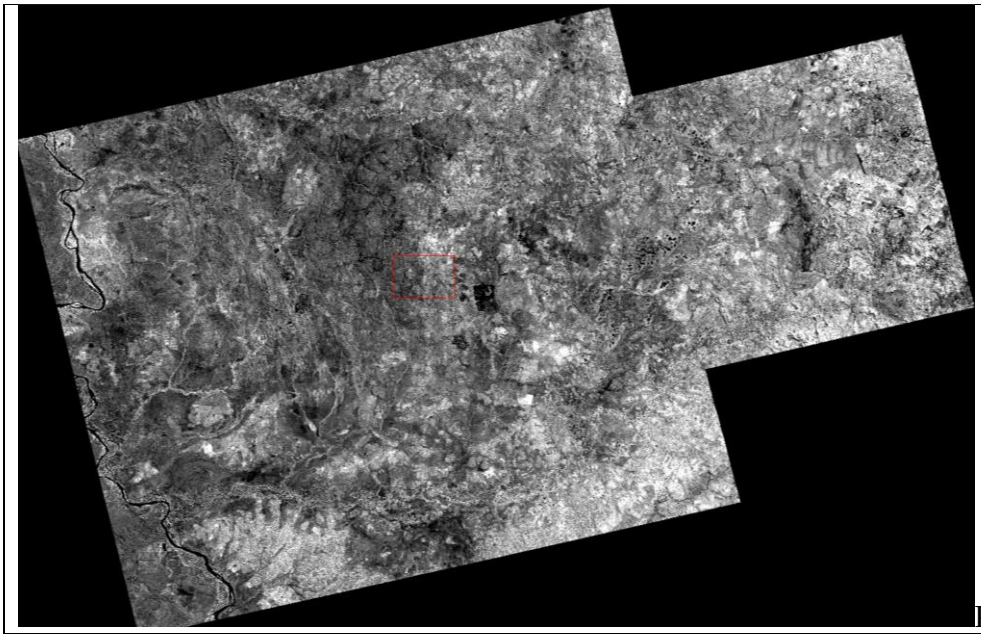


SV classifier is a pixel-based classification was used along with unsupervised methods performing region growing and segmentation on selected areas followed by agglomerative clustering of the pixels. A maximum likelihood classification with an integrated filter to help overcoming the effect of speckle was applied. Same algorithm can be use in a supervised way. Both supervised and unsupervised methods are used for the analysis

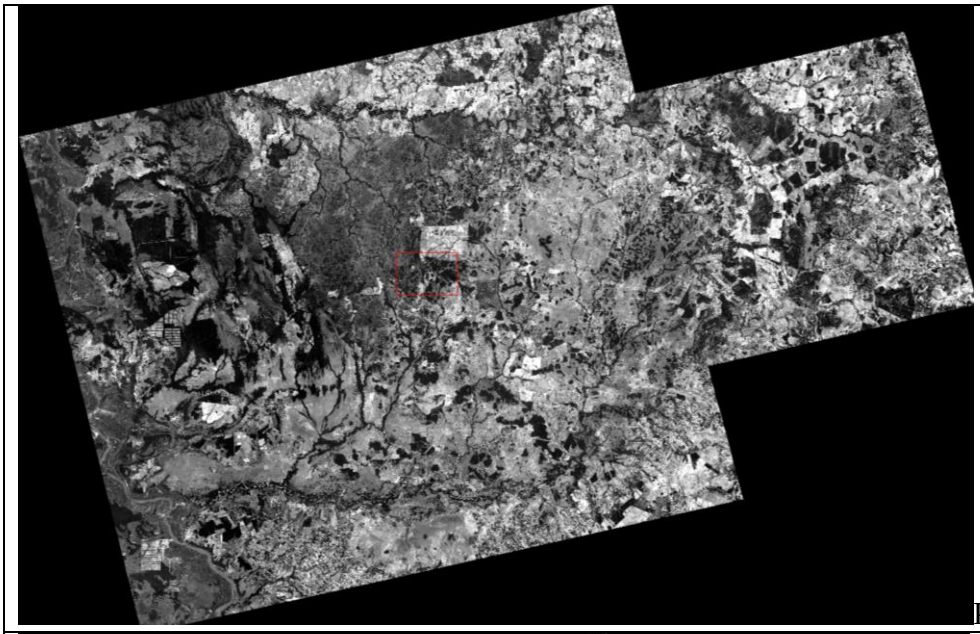
The images used were generated using the Google Earth Platform. The algorithm was used to remove clouds from the sentinel-2 images found in the following link. https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S2_CLOUD_PROBABILITY. For each of the years (2016, 2019 and 2021) the algorithm was run with the minimum number of images necessary to reach a compound free of clouds and atmospheric effects. In general, preference was given to include images of the months between November and March of each year to include the summer season, when vegetation is well developed, and water levels are high. For example, to make the compound of the Year 2019 images were used between Nov 2018 and April 2019 and for the compound of the year 2021 images were used from Nov 2020 to June 2021. Filters for cloud removal were adjusted to 10%

The resulting compounds contained the information of the bands "B8", "B4", "B3", "B2", "B5" of the Sentinel-2 system. These Bands were used for the calculation of different indices: TCG - Tasseled Cap Greenness. TCW - Tasseled Cap Wetness. NDVI- Normalized vegetation Index PCA – Principal components (3 PC's) These images were processed using the ENVI program, for the management and processing of remote sensor images. The Main Components PC1 and PC2 and the NDVI were shown to be images containing the largest amount of information according to the statistical spectral distance and Mahalanobis. The following figure shows the black and white images for these indexes.

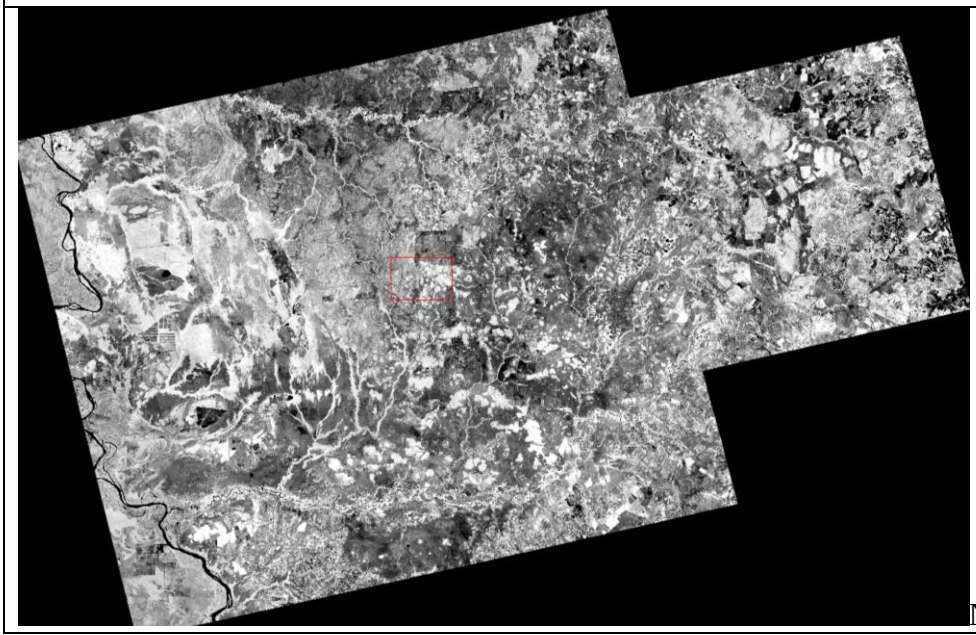




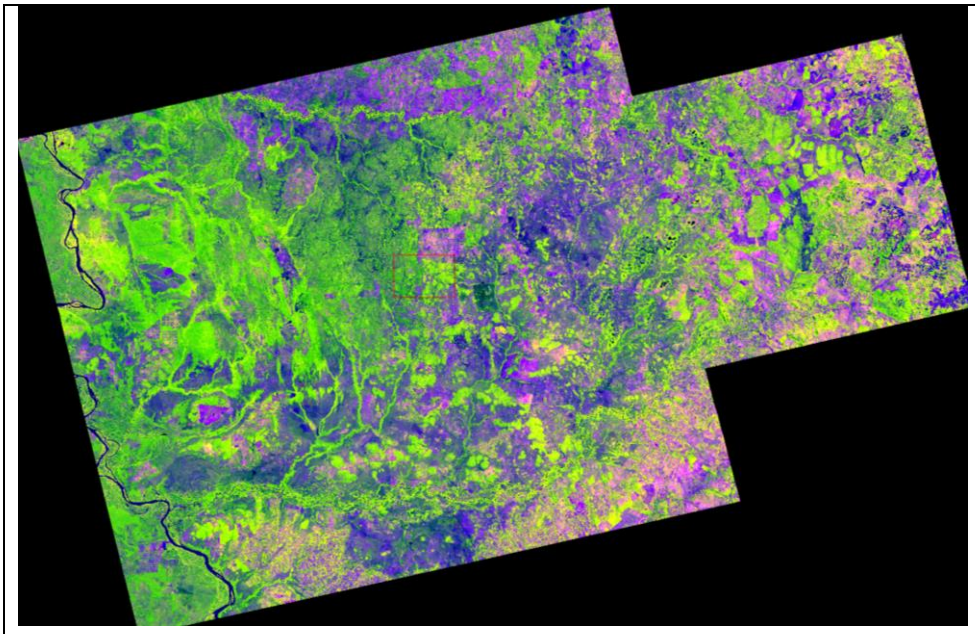
PC1



PC2



NDVI



Compuesto de color

A color compound was made using the selected images. A basic interpretation of this color compound shows: Dense forest vegetation = bright green) Less dense Cerradón vegetation =dark green Open vegetation areas of non-forest = blue and magentas Crop or pasture areas = Magenta Areas with little vegetation = blue Areas with flooding or high soil moisture = dark blue Sentinel-1 and Alos PALSAR-1-2 radar images were used as complementary images for separations of dense forest classes and flood analysis. The following images show these different images.

Outline of the preprocessing and classification steps of the images used.

- Creation of mosaic-without clouds using the Google Earth platform.
- Quality review of images between dates.
- Analysis of differences of spectral signals between the mosaics of the different dates, in areas of selected polygons.
- Calculation of spectral indices
- Calculation of statistical distance between images.
- Selection of bands for classification.
- Recording of optical images and radar images, with a resolution of one pixel.
- Study of colour compounds in relation to the available information on vegetation types in the study area.
- Selection of areas of interest (polygons) within the images, labelled with a possible class or type of vegetation.
- Analysis of class separability using the Matusita distance. Spectral definition of vegetation types using the selected pixels as spectral seeds. (purity index analysis).
- Statistical analysis of spectral samples for each vegetation class
- Maxim Likelihood Classification, supervised of the image using the classification algorithm developed in SarVision (SAR-Class). This algorithm allows the use of radar images in classification and generates post-processing to lessen the effect of radar speckle on classification.

- Post processing of the classification. Cluster analysis between the average values calculated by class for all available images.
- Union of thematic classes with similar statistical distances. Definition of final legend with statistically different classes.
- Post processing to add available ancillary information. (cities, roads and drains). Definition of colour palette.

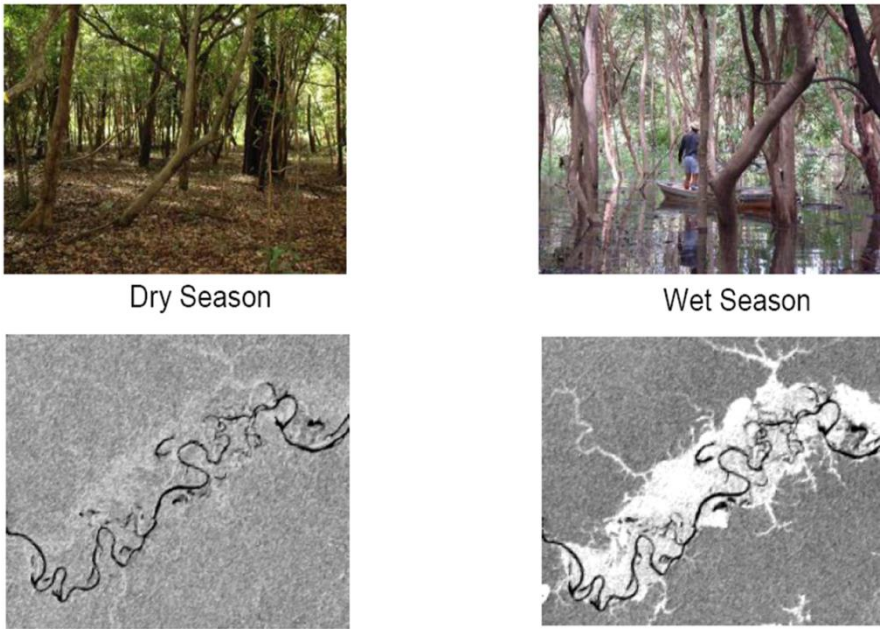
Methodology for Flood Analyses

The mapping of the flooding for both radar systems (Alos PALSAR and Sentinel-1) can be explained, relatively easy. Both the biophysical mechanism involved between the radar wave interaction with the terrain and the mapping algorithm can be clarify.

In the case of PalSAR images the HH polarization can detect the flood under the canopy due to the occurrence of a scattering mechanism called double bounce. The radar wave penetrates the canopy of the forest and interacts with both the flooded terrain under the canopy and the trunk of the trees, creating a return wave with a high intensity, that appears bright in the radar images.

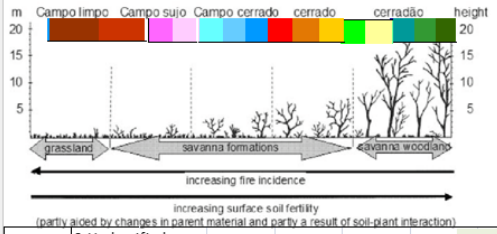
These images can be then classify using different algorithms into flooded and not flooded forest. A simple algorithm for classification is a density slicing, that allow the classification of the high return values from the images. This classification needs to be corrected for different types of radar effects like speckle and slopes and needs to be done in combination with a Land cover map that specifically shows the location of the forest and built-up areas, since double bounce effects can also occur in both land cover types.

In the case of the Sentinel-1 system, Flooding on open terrain can be detected by the occurrence of a reflection of the radar wave on the flooded terrain, resulting on very low backscatter since the wave energy will be reflected away from the radar. In this case the classification also required the information of a land cover map where flooding on open terrain can be distinguish from open water. Simple classification algorithms like density slicing can be used.



Alos PalSAR Radar images in dry season and wet season. The flood under canopy can be clearly seen in the image on the right, in the whitest area next to the river. The classification of this image can be easily done using the definition of spectral limits.

WP1- Legend used for the three Land cover maps.



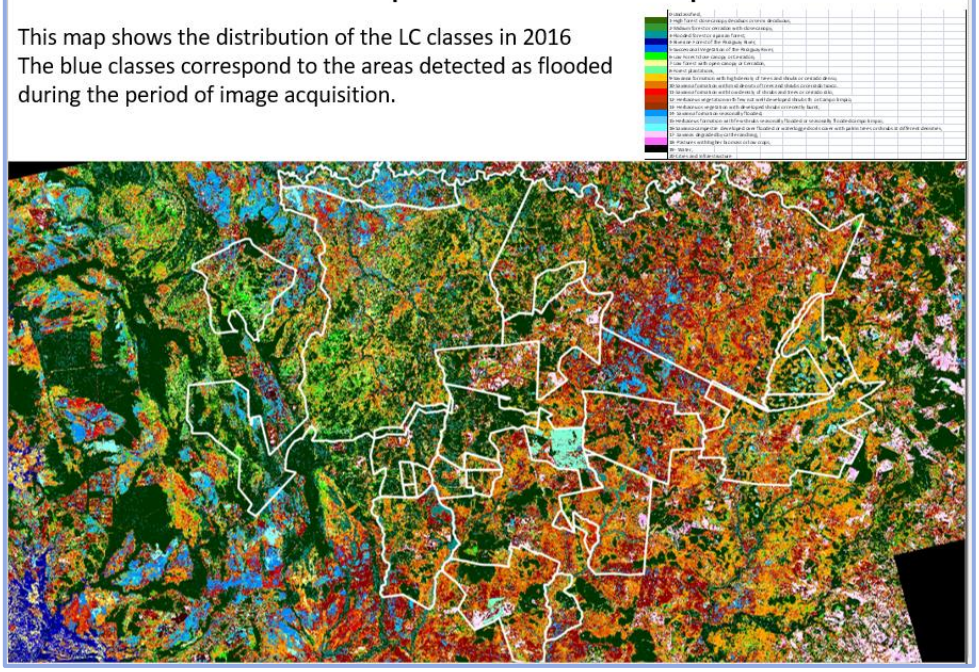
For the classification of the Maps the same Remote sensing bands and classification methods were used to create consistency between the maps. All maps used the same legend to allow the comparison between the dates

Legend used for the description of the vegetation for all the years 2016, 2019 and 2021

0-Unclassified,
1-High forest close canopy deciduos or semi deciduous,
2-Midium forest or cerradon with close canopy,
3-Flooded forest or riparian forest,
4-Riverine Forest of the Paraguay River,
5-Succesional Vegetation of the Paraguay River,
6-Low Forest close canopy or Cerradon,
7-Low forest with open canopy or Cerradon,
8-Forest plantations,
9-Savanna formation with high density of trees and shrubs or cerrado denso,
10-Savanna formation with mid density of trees and shrubs or cerrado tipico,
11-Savanna formation with low density of shrubs and trees or cerrado ralo,
12- Herbaceus vegetation with few not well developed shrubs th or Campo limpio,
13- Herbaceuos vegetation with developed shrubs or recently burnt,
14- Savanna formation seasonally flooded,
15-Herbaceus formation with few shrubs seasonally flooded or seasonally flooded campo limpio,
16-Savanna campestre developed over flooded or waterlogged soils cover with palms trees or shrubs at different densities,
17- Savanas degraded by cattle ranching,
18- Pastures with higher biomass or low crops,
19 - Water,
20-Cities and Infraestructure

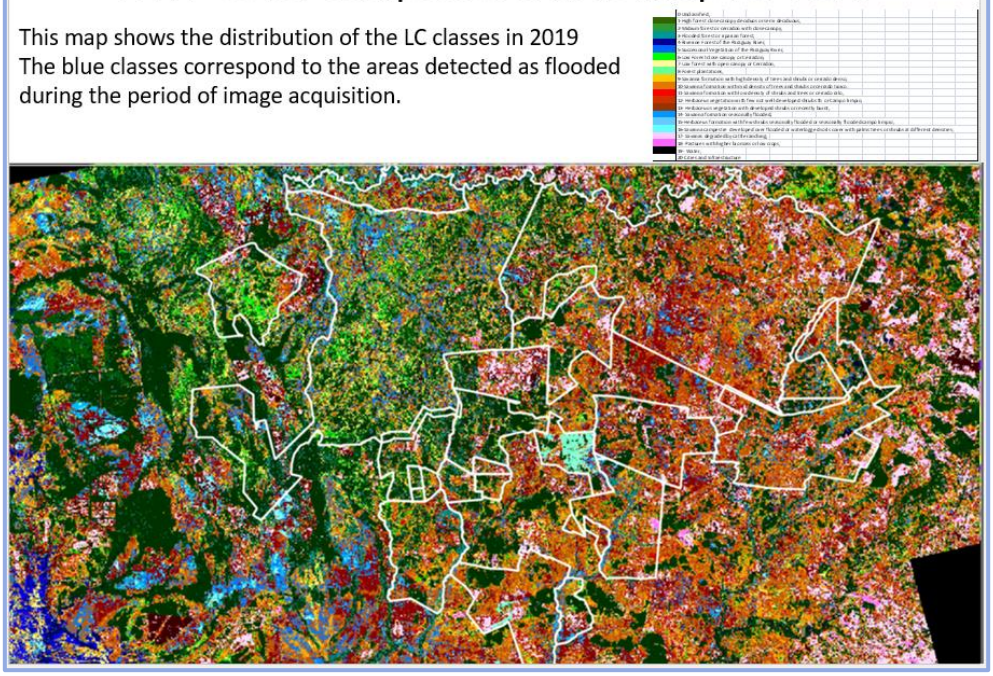
WP1- Color composite and LC Map for 2016

This map shows the distribution of the LC classes in 2016
The blue classes correspond to the areas detected as flooded during the period of image acquisition.



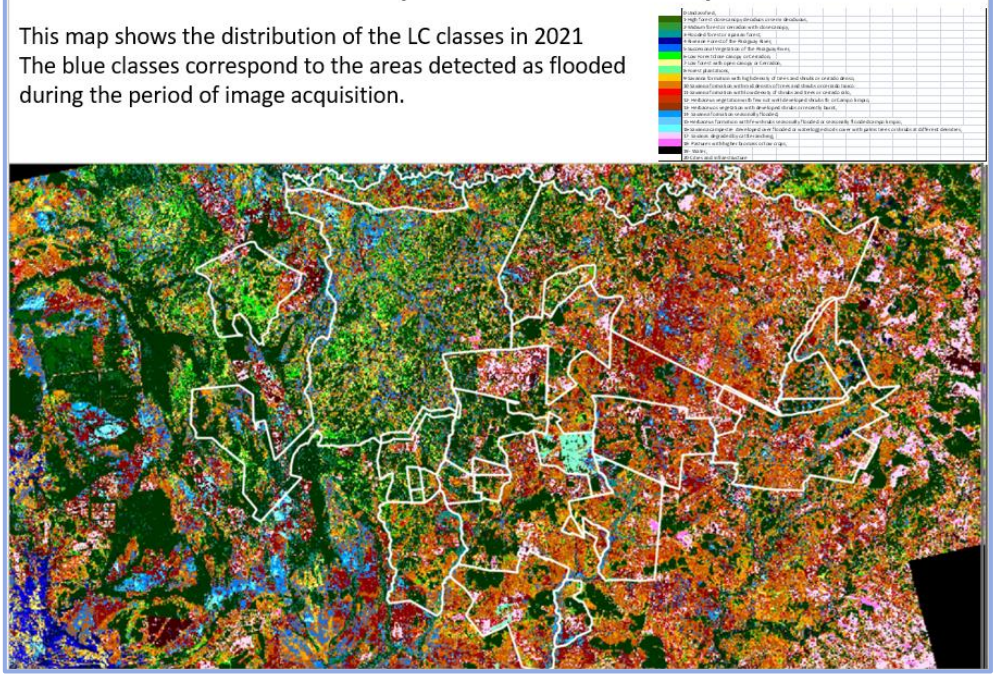
WP1- Color composite and LC Map for 2019

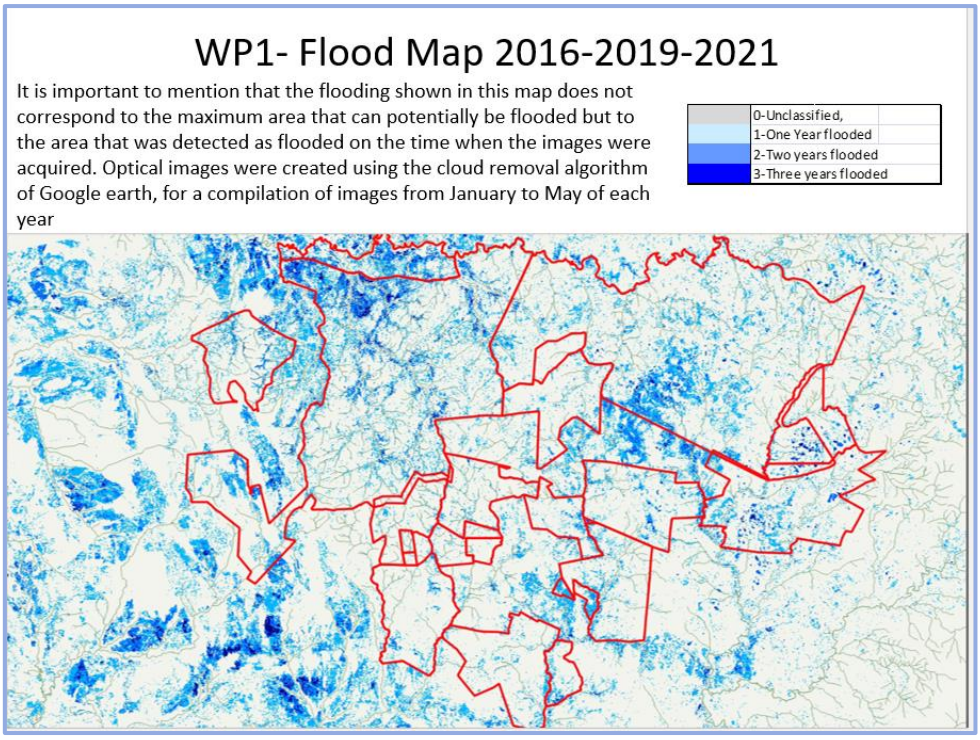
This map shows the distribution of the LC classes in 2019
The blue classes correspond to the areas detected as flooded during the period of image acquisition.



WP1- Color composite and LC Map for 2021

This map shows the distribution of the LC classes in 2021
The blue classes correspond to the areas detected as flooded during the period of image acquisition.





Ground verification

Vegetation condition and maps produced with satellite imagery were validated in the field in April 2022. A total of 200 randomly assigned (in proportion to the relative abundance of modelled vegetation classes) validation points were sampled from 15 Paracel properties and evenly distributed across the landscape.

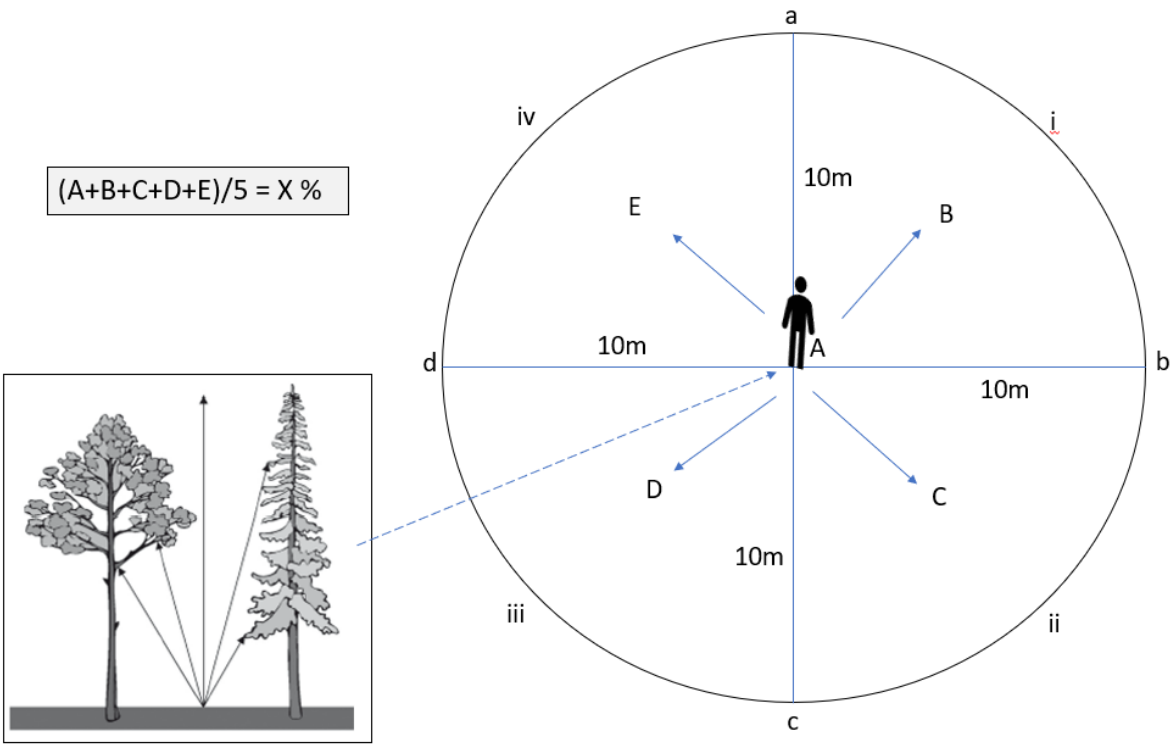
Methodology summary:

- Canopy cover percentage was estimated within a circular 10m radius plot measured from the centre of each validation point.
- Mean, and maximum canopy height measurements were collected using a hypsometer.
- Ground cover measurements were collected within a circular, 10m radius plot measured from the centre of each validation point.
- Evidence of permanent or seasonal flooding was recorded from each point.
- For crops, the type of crop (e.g., soy or corn) was noted
- Exotic or native pastures were recorded.

Instructions (in Spanish) used by the validation team in the field are copied in the following pages:

Cobertura de doseles

1. Se solicita que las observaciones estructurales se realicen en un radio de 10 metros desde el punto en el que se ubica el observador.
2. Las clases de vegetación modelada ya existen en los atributos, asegúrate de que no influyan en tu observación. Este ejercicio de validación está diseñado para comprobar la precisión de todas las clases mapeadas, por lo que se necesitan observaciones que sean imparciales.
3. Si se encuentra que un punto se sitúa en el borde entre clases de vegetación observada en el campo, mejor evitarlo, ya que la precisión del GPS suele ser de hasta 15 metros.
4. A la hora de determinar el **% de cobertura del dosel**, seguir el protocolo indicado en este diagrama y las instrucciones:



Representación de un punto de validación de 10 metros de radio

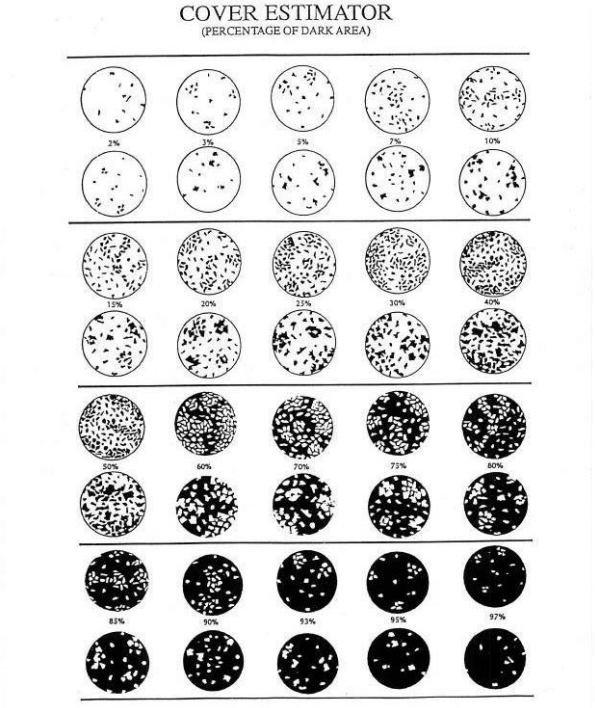
Ayudándose de este diagrama, seguir los siguientes pasos:

- El observador primero se ubicará sobre el punto GPS solicitado (A).
- Un asistente colocará una marca a 10 metros del observador cada 90º de ángulo (en a, b, c y d).
- El observador camina por el interior de la parcela circular, estudiando los límites de la parcela y la estructura del dosel para familiarizarse. Esto reduce la parcialidad, y permite al observador conocer los límites de la parcela, en el momento en el que se posiciona sobre los puntos de estimación.

- A continuación, el observador camina por todo el interior de cada cuadrante y luego regresando al punto central del cuadrante (B, C, D y E) se toma una estimación del % de cobertura de dosel de cuadrante (efectivamente por un radio de aproximadamente 5 metros de los puntos centrales y tomando en cuenta la caminata), así pasando por los cuadrantes en torno y terminando con punto A. Para ello, estimar la cobertura del dosel (% de cielo ocultado por vegetación). El dosel en este caso se entiende como toda la vegetación que bloquea la luz solar entre la altura del pecho y la altura máxima del arbusto o árbol más alto. Aclaración: Si hubiera un arbusto con un árbol encima, no se debe de contar el dosel dos veces. En el diagrama de a continuación, el dosel dentro de la circunferencia correspondería a toda el área que no es azul:

Representación para la medición del porcentaje de cobertura del dosel

- Para terminar, sumar las estimaciones de A, B, C, D y E, y dividir el resultado entre 5 para obtener el % de cobertura promedio para ese punto de validación concreto.
- Ayudarse del siguiente diagrama (asegurarse de tener una copia impresa en todo momento del Apéndice 2) a la hora de estimar el %, ya que en muchas ocasiones la estimación de la observación puede ser confundida dependiendo de cómo se estructura el % de cobertura:



Plantilla de ayuda al observador a la hora de realizar estimaciones del porcentaje de dosel, evitando la parcialidad y confusión

Tomar cuatro fotografías geolocalizadas con una lente gran angular (35mm o menos) desde los puntos i, ii, iii y iv, los cuales sean una fotografía cada 90º del punto de validación.

Observar y anotar signos de inundaciones en cada lugar.

Medición de alturas de doseles

Para la medición de las alturas de los doseles de árboles y arbustos, se deberá de realizar mediciones de alturas promedias, y de alturas máximas.

Altura promedio: Emplear un hipsómetro con el que se deberán de tomar cinco mediciones verticales para cubrir la variación. A continuación, dividir entre cinco, y anotar la altura media.

Altura máxima: Medir tantas muestras como sean necesarias con el hipsómetro, basándose en la observación visual de qué árboles y arbustos son los más altos. Anotar el dosel más alto.

Medición de altura promedio de hierbas o graminoides

Esta medición puede ser realizada a ojo, de la altura de hierbas o graminoides que se encuentren por debajo de 1.35m (altura del pecho).

Medición de la cobertura vegetal total del suelo

La metodología para esta medición es una simplificación de la estimación de cobertura de doseles. Se aplicará tanto para la cobertura vegetal del suelo, como para la estimación de cobertura de especies invasoras.

- El observador camina por el interior de la parcela circular, estudiando los límites de la parcela y la estructura de la cobertura vegetal para familiarizarse.
- Realizar una estimación de la cobertura vegetal de los cuadrantes B, C, D, E (no es necesario el A) de la Figura 1 de este protocolo. Dividir entre cuatro para obtener el porcentaje de cobertura vegetal total del suelo.

¿Cuántos puntos recoger?

Se cubran todas las clases de vegetación en 200 puntos en proporción de su presencia, esparcidos por las propiedades y se cubran en las siguientes proporciones:

Clase	% de puntos de muestreo por clase
1- Bosque alto	18
2- Bosque medio	1
3- Bosque Ripario	4
4- High Forest Chaco	2
5- Low Forest Chaco	3
6- Cerradón	1
7- Cerradón 2	2
8- Plantación forestal	1
9- New Forest Plantation	14
10- Harvested Plantations	9

11- Campo Sucio	9
12- Campo limpio	7
13- Savanna Dry:	1
14- Savana Dry 2:	2
15- Bare or degraded land	2
16- Savannas seasonally flooded 1	1
17- Savannas seasonally flooded 2	5
18- Inundated savanas	3
19 - Zonas detectadas como cultivos o pasturas.	1
20- Zonas detectadas como cultivos o pasturas.	1
21 - Zonas detectadas como cultivos o pasturas.	1
22- Agua	1
23 – Infraestructura	2
24 - Bosque degradado: bosque con dosel cerrado o abierto con degradacion visible	8

La tabla que se muestra a continuación será utilizada para cada uno de los puntos de validación:

Informacion general	Punto de validación 1	
Fecha de adquisición		
Nombre de la propiedad		
Condiciones meteorológicas (lluvia, nublado, soleado)		
Punto ID# en archivo shape:		
SarVision mapa LandCover class ID		
Cuadrícula en el mapa		
Latitud y Longitud		
Numeros de Fotografias georeferenciadas		
Observed Landcover / tipo de vegetacion observada	Indicar con una X	Anotaciones
1- High Forest: Bosque alto: Bosque alto con dosel cerrado, biomasa alta. No inundado		
2- Mid Forest: Bosque medio, de altura media o menor densidad o nivel medio de biomasa. No inundado		
3- Riparian Forest: Bosque Ripario. Bosque a lo largo de los ríos con dosel cerrado y alto nivel de biomasa. Se marcan algunas de las áreas detectadas como estacionalmente inundadas.		
4- High Forest Chaco: Bosque alto de dosel cerrado y alto nivel de biomasa a las orillas del rio Paraguay, se encuentra hasta una altura de 100 metros sobre el nivel del mar		
5- Low Forest Chaco: Bosque bajo de dosel abierto, con nivel medio de biomasa.		
6- Low forest close canopy o Cerradón: Bosque bajo o de baja densidad, dosel semiabierto y un nivel de biomasa media. En zonas de cerrado puede considerarse como un Cerradón		

7- Open canopy foresto or Cerradón 2: Bosque bajo o poco denso de dosel abierto y nivel de biomassa mas bajo. Puede considerarse como cerradon.		
8- Forest Plantation: Plantación forestal, bosque plantado de dosel cerrado con un nivel alto de biomasa.		
9- New Forest Plantation: áreas recientemente plantadas de bosque. Se uso la información de Paracel para separar estas clases en zonas donde se detectó esta cobertura.		
10- Harvested Plantations: Esta clase incluye zonas que fueron detectadas en 2016 como plantadas con arboles y que fueron cosechadas		
11- Shrublands (o tree shrubland) high density: Campo Sucio: Zonas abiertas pertenecientes al cerrado con arbustales o arboles con una densidad de alta a media. Area Natural		
12- Shrubland (o tree-shrubland) low density: Campo limpio: zonas abiertas de cerrado con una densidad baja de arbustos o arboles. Area Natural		
13- Savanna Dry: Zonas de sabanas secas con vegetación graminoidea dominante de media o alta densidad.		
14- Savana dry 2: Zonas de sabanas secas con vegetación graminoidea dominante de media o baja densidad.		
15- Bare or degraded land: Areas de sabanas con muy baja biomasa o zonas de suelo abierto. Zonas degradadas		
16- Savannas seasonally flooded 1: Areas de sabana identificadas en zonas de drenajes y de suelos muy húmedos.		
17- Savannas seasonally flooded 2: Areas de sabana identificadas en zonas de drenajes y de suelos muy húmedos. Similar a la anterior		
18- Inundated savanas: Sabanas permanentemente inundadas con muy poca vegetación graminoidea.		
19-20-21 - Crops or pastures 1-2-3: Zonas detectadas como cultivos o pasturas.		
22- Agua		
23 Infraestructura		
24 Bosque degradado: bosque con dosel cerrado o abierto con degradacion visible		
Caracteristicas estructurales del vegetacion		
Cobertura total de dosel árboles y/o arbustos (%). Ver Sección 3, punto 4 de Cobertura de doseles del Protocolo para la validación del mapa de vegetación		
Altura promedio del dosel de árboles (metros), en árboles de más de 2 metros		
Altura promedio del dosel de arbustos (metros):		
Altura maxima del dosel de árboles (metros):		
Altura maxima del dosel de arbustos (metros):		
Altura promedio de ground layer (<1.35M) - hierbas o graminoides (metros)		
Cobertura vegetal total del suelo (%) (ground layer de <1.35m) (requirido solo por classes 11-21). Ver Sección 3, Medición de la cobertura vegetal total del suelo, del Protocolo		

Humedad del suelo (conocimiento local parcialmente requirida)		
Suelo comprimido/agrietado		
Suelo húmedo en el que puedan crecer herbáceas		
Suelo inundado permanentemente		
Suelo inundado estacionalmente		
Suelo donde se ve el drenaje del agua		
Régimen de inundaciones (conocimiento local parcialmente requirida)		
Es una zona que se inunda?		
Si se inundada cual es la estacionalidad (# dias o meses)		
Inundacion permanente		
Cultivos (cuadrante de 10x10m)		
Soja		
Maíz		
Otros (especificar cuál, si es posible)		
Tipo de cultivo		
Anual		
Perenne		
Zonas de pastoreo		
Pasto foraneo		
Pasto natural		
Especias invasoras ground cover estimate		
Cobertura vegetal de especies invasoras total del suelo (%), para clases 11-18. Ver Sección 3, Medición de la cobertura vegetal total del suelo del protocolo		

Table 5: List of first iteration modelled vegetation classes validated in the field

1- High Forest with high canopy and high biomass
2- Mid Forest with intermediate canopy, and lower biomass
3- Riparian Forest
4- High Forest Chaco: High forest with high biomass along the Paraguay river shores
5- Low Forest Chaco: Low forest with open canopy, and intermediate level of biomass
6- Cerradón: Low forest with low density and semi-open canopy
7- Cerradón 2: Low forest with low density and close canopy
8- Forest Plantation with close canopy and high biomass
9- New Forest Plantation: Areas recently planted
10- Harvested Plantations: Detected in 2016 as planted and that were harvested
11- Campo Cerrado: Shrublands (or tree shrubland) with high density
12- Campo Sucio: low density open areas with low density of shrubland
13- Dry Savanna with high to intermediate density of graminoids
14- Dry Savanna 2: With intermediate to low density of graminoids
15- Bare or degraded land

16- Seasonally flooded savanna 1
17- Seasonally flooded savanna 2
18- Inundated savannas with very few graminoids
19-20-21 - Crops or pastures
22- Water bodies
23- Infrastructure
24- Degraded forest with closed or open canopy with obvious degradation

Figure 4: Matrix showing the distribution of the vegetation classes estimated (rows) and observed (columns) after the field validation process.

Clase según mapa	Clase observada en terreno																					Total puntos validados
	1	2	3	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	37		1																				38
2	1	1			2																		4
3		1	4																				5
6					1									1									2
7					4						1			1			1						7
8						1																1	2
9						4	1						2										7
10						4																	4
11							1		4		5		3	10			5					1	29
12						1	2		4	2	2	1		7			2						21
13					1				1		7	1				1							11
14						1	3		1		1	9	1				7						23
15						1	1						3							1			6
16					1	1						1											3
17													1		2		1						4
18														1									1
19									1		1		1	1			4						8
20									1									1					2
21					1						1						1		1				4
22			1																	1			2
23			1											1			1				2		5
24				2	1																	9	12
Total puntos validados	38	2	7	2	11	13	8	0	12	2	18	12	11	22	2	1	22	1	1	2	2	11	**200**

Validation information was used to modify the vegetation classes and then these were subsequently amalgamated by Nature Positive for the purposes of mapping, as per Table 6.

Table 6: Post validation vegetation classes and aggregated classes for simplified mapping (colour coding matches Figure 3 map).

Post Validation	NP Aggregated
1-High forest (closed canopy deciduos or semi deciduous)	Dry Forest
2-Medium forest (or cerradon with close canopy)	Dry Forest
3-Flooded forest or riparian forest	Riparian Forest
4-Riverine Forest of the Paraguay River	Riparian Forest
5-Succesional Vegetation of the Paraguay River	Riparian Forest
6-Low Forest closed canopy (or Cerradón)	Dry Forest
7-Cerradón	Dry Forest

8-Forest plantations	Forest Plantations
9- Campo Cerrado	Dry Savanna
10- Campo Sucio	Dry Savanna
11- High savanna with woody species	Dry Savanna
12- High savanna without woody species	Dry Savanna
13- low vegetation with developed shrubs or recently burnt	Dry Savanna
14- Savanna formation seasonally flooded	Wet Savanna
15- low vegetation with few shrubs seasonally flooded or seasonally flooded	Wet Savanna
16 -Savanna over flooded or waterlogged soils (with palms or shrubs at different densities)	Wet Savanna
17 - Erosion or savanna heavily degraded by cattle ranching	Crops/Pastures
18 - Higher biomass pastures or low crops	Crops/Pastures
19 – Water	Water
20 – Built	Built

Appendix 2: Justifications for species qualification results under IFC criteria 1 & 2

Table 7: Justifications for Species qualification results under IFC criteria 1 & 2

Criterion 1a				
Taxon	**IUCN status**	**National list**	**Category**	**Justification**
Plants				
Discocactus hartmannii	**CR**	**EP**	Possible	This is a Critically Endangered species found within a limited geographical range which grows in the Cerrado, in between grasses (Ana Pin, personal communication, 18th of February 2022), but is also found in the Chaco and in some Protected Areas (Fatima Mereles, personal communication, 1st of February 2022). Very few specimens of this species have been historically collected, and there is a lack of current information about *Discocactus hartmannii*. This species is listed in the Appendix I of the CITES. Therefore, it can be of value for collectors (Ana Pin, personal communication, 18th of February 2022).
Fish				
Hyphessobrycon wajat	**DD**	**-**	Possible	This Data Deficient species is shown by the IUCN as distributed within the AoA, with an overlap of 10.50%, and down south to Asuncion, and within the same latitude this species may be distributed over the Región Occidental of Paraguay, and across the border with Argentina. Further information about this species is required to determine whether it could belong to a category other than possibly qualifying.
Reptiles				
Phalotris nigrilatus	**EN**	**EP**	Possible	This colubrid snake is endemic to San Pedro Department, and is known from a very few historical specimens (Cacciali et al., 2020) . Individuals are normally difficult to find. Being threatened, it obviously has conservation significance. (Hugo Cabral, personal communication, 20th of January 2022). More information is required to define a category other than Possible for this species.
Birds				
Amazona vinacea	**EN**	**EP**	Possible	This globally endangered and nationally threatened species is likely to have a decreasing population, currently in the range of 1000-2499 mature individuals, and IBAT returns an Extent of Occurrence of 534,683 km^2. The distribution range of the Vinaceous-breasted Amazon overlaps with the AoA, as shown by the IUCN Geographic range map. On the other hand, GBIF shows no occurrences in the AoA.
Harpyhaliaetus coronatus	**EN**	**AE**	Possible	IBAT results show that the 0.45% of global distribution of this species overlaps with the AoA, very close to the 0.5% threshold, considering that the IUCN's global population estimates is thought to be in the range of 250-999 mature individuals,

				and decreasing. With an Extent of Occurrence of 4,234,481km2, both the IUCN and GBIF show distribution of *Harpyhaliaetus coronatus* in the AoA. This species can be also found elsewhere in Paraguay, and in Argentina, Bolivia, and Brazil.
Sporophila palustris	**EN**	**EP**	Possible	IBAT returned a 0.46% of overlap of the global distribution of this species with the AoA.. Its population, estimated to be 600-1700 mature individuals is decreasing. The IUCN database shows that the AoA, and the northern part of the department of Amambay, are the only breeding areas for this full migrant species in Paraguay. Further investigation is required to confirm the presence of this species in the AoA. Experts consulted did not provide any information on this species. This species is also nationally listed by the MADES as “En peligro de extinción” and included under the Criterion 1c as Likely.

Criterion 1c				
Taxon	**IUCN status**	**National list**	**Category**	**Justification**
Plants				
Bactris glaucescens	**-**	**EP**	Likely	There is no information on the distribution of this species on the IUCN data base. However, GBIF shows that more than 50% of the records in Paraguay have been found in the AoA. More information may be required, and no experts commented on this species.
Gymnocalycium anisitsii	**LC**	**AE**	Likely	IBAT shows that the range of this species is of 4701.74km2, with a 34.8% overlap with the AoA. The IUCN map shows nearly 100% of the distribution of Paraguay to be inside of the AoA, outside of the properties. The GBIF data base shows more than 50% of the records in Paraguay to be found in the AoA. More evidence on this species is required to support qualification as Critical Habitat under IFC PS6. Ana Pin (personal communication, 18th of February) mentioned that this threatened species is found in the project area, in sandy soils of the savanna.
Myroxylon peruiferum	**LC**	**EP**	Likely	The IUCN database shows that the only distribution of this species in Paraguay is in the AoA, and IBAT did not return any results on this species. Its distribution is broad in Brazil, Bolivia, Peru and Ecuador. More information would be required to support qualification as Critical Habitat, but the information available shows that this species likely qualifies the AoA as Critical Habitat
Syagrus oleracea	**-**	**EP**	Likely	Only found in AoA nationally according to GBIF, IBAT and IUCN do not return any results *on Syagrus oleracea*. Its distribution is broad in Brazil, and more information would be required to confirm qualification as Critical Habitat.
Amburana cearensis	**EN**	**EP**	Possible	In a personal communication, Fatima Mereles (1st of February, 2022) mentioned that this species is very abundant in the north and north-eastern Chaco.

				The IUCN does not show distribution information, and GBIF shows ca.25% of the Paraguay records in the AoA.
Balfourodendron riedelianum	**EN**	**EP**	Possible	This species has been found in the AoA, with GBIF showing ca.25% of the Paraguay records in the AoA. It is not very abundant, and can also be found in the Atlantic Forest, and in the Reserves of Itaipú (Fatima Mereles, personal communication, 1st of February, 2022). AoA records in GBIF. GBIF around 25% of records from PY in the AoA. Its distributional range in Brazil is broad.
Dimorphandra mollis	**LC**	**EP**	Possible	There is very limited information available on this nationally threatened species, and GBIF shows two records, one in Brazil bordering the AoA. Experts did not return comments on this species. IBAT and the IUCN do not show any results
Discocactus hartmannii	**CR**	**EP**	Possible	This is a Critically Endangered species found within a limited geographical range (Ana Pin, personal communication, 18th of February 2022), but is also found in the Chaco and in some Protected Areas (Fatima Mereles, personal communication, 1st of February 2022). Very few specimens of this species have been historically collected, and there is a lack of current information about *Discocactus hartmannii* (Ana Pin, personal communication, 18th of February 2022).
Frailea schilinzkyana	**VU**	**EP**	Possible	in a personal communication (18th of February 2022) Ana Pin mentioned that there are very few botanical records of this restricted range species (IBAT shows 47,000km2), and a lack of updated information on this species. *Frailea schilinzkyana* can be found in pasture areas, in the savanna, and over soils with rocky outcrops. Its population is decreasing, and IBAT showed a 3.62% overlap with the AoA.
Trichilia stellato-tomentosa	**LC**	**EP**	Possible	There is no IUCN distribution map on this species. GBIF shows 50% of the records in Paraguay to be bordering the AoA, and more records also in Brazil and Bolivia
Amphibians				
Dendropsophus elianeae	**LC**	**EP**	Possible	Diego Bueno Villafañe (personal communication, 29th of January 2022) explained that all individuals were found in Amambay and Concepción, and he has found them in riparian forests of the PARACEL properties, where he found five of them, always resting on the leaves of *Vernonanthura brasiliana*, at about one metre height. In a personal communication, Hugo Cabral (20th of January 2022) indicated that this is an endemic species of the Cerrado in Brazil and Paraguay. Hugo Cabral suggested that as the Cerrado in Paraguay is restricted to that portion of the territory, perhaps the species is present in more locations. IUCN shows that the AoA may contains half of the Paraguayan distribution of this species. GBIF shows no distribution for this species.
Reptiles				

Bachia bresslaui	**VU**	**-**	Likely	Hugo Cabral (personal communication, 20th of January, 2022) reported that this is a rare species in Paraguay, endemic to the Cerrado, in Brazil and Paraguay, and a globally threatened species. recommended that more field campaigns should be conducted to search for this species.
Eunectes murinus	**LC**	**AE**	Likely	This species reaches the southern limit of its distribution in Paraguay. Hugo Cabral (personal communication, 20th of January, 2022) always found this species associated with relatively conserved environments in Brazil. It has a fairly wide distribution globally, however, in Paraguay it is restricted to Amambay and San Pedro, with records in Canindeyú as well. The species could be present in Concepción as well, and the IUCN map shows that it may be distributed towards the eastern parts of the AoA. This species is important for the leather industry, and as a pet.
Salvator duseni	**LC**	**EP**	Likely	This species, shown by the IUCN to be distributed in the eastern section of the AoA, and with more than 25% of the distribution in Paraguay within the AoA, is associated with the Cerrado, and has relatively few records in Paraguay (Hugo Cabral, personal communication, 20th of January 2022). It is a species prized for leather and perhaps as a pet.
Chelonoidis carbonaria	**-**	**EP**	Possible	Diego Bueno Villafañe (personal communication, 29th of January 2022) explained that this species may be critically endangered in the near future, due to habitat alteration in the Chaco, illegal hunting for consumption or to sell to collectors, and the large fires that are being currently seen in the region. He and others found it in the PARACEL properties in well preserved riparian forest, and they also found a calcined shell in a low area of floodable savanna. Villagers say they are frequently seen. There is no IUCN information on this species.
Norops meridionalis	**-**	**EP**	Possible	The IUCN shows that more than 25% of its distribution within Paraguay may be in the AoA. Diego Bueno Villafañe, in a personal communication (29th of January 2022), explained that this species is endemic to the Cerrado and in Paraguay is found in Canindeyú, Concepción, and San Pedro (Cacciali et al. 2016). Citing Vitt, 1991 and Vitt & Caldwell, 1993, Diego Bueno Villafañe noted that *Norops meridionalis* inhabits open forests and savannas from sunrise to sunset, where in a short range of action (less than $10m^2$) it uses shrubs, termite mounds, rocks and caves to forage and hide, but can also climb low vegetation. There are few records and data on the species in the country, although in other countries it is considered abundant. In the P.N. San Luis he recorded it on one occasion, climbed in the low stratum in open forests of the Cerrado, between the formations of Cerrado and Cerradón which coincides with previous observations on the species. Diego Bueno Villafañe reckons that the presence of this species is highly likely in the PARACEL properties. Hugo Cabral (personal communication, 20th of January, 2022) suggests

				that this species requires a taxonomic revision, as it may be more than one species.
Phalotris nigrilatus	**EN**	**EP**	Possible	This colubrid snake is endemic to San Pedro Department, and is known from a very few historical specimens (Cacciali et al., 2020). Individuals are normally difficult to find. Being threatened, it obviously has conservation significance. (Hugo Cabral, personal communication, 20th of January 2022). More information is required to define a category other than Possible for this species.
Birds				
Alipiopsitta xanthops	**NT**	**AE**	Likely	The only accessible records of the yellow-faced parrot in Paraguay are present in the AoA, although its distribution is broad distribution in Brazil and Bolivia. In a personal communication on the 25th of February, LoraKim Joyner and Andrés Álvarez commented on the importance of this species for Paraguay, as it has been recently found in the area, and there is little information on this bird species. These parrots are known to nest in termite mounds (unlike other parrots), and this makes them highly vulnerable to agricultural and forestry practices. LoraKim Joyner and Andrés Álvarez also reported that this species is highly sensitive to habitat fragmentation and hunting.
Anodorhynchus hyacinthinus	**VU**	**EP**	Likely	The IUCN shows that almost half of the distributional range of this species in Paraguay is in the AoA. GBIF, shows all records from Paraguay, but one, to be in the AoA. Outside Paraguay is common, and IBAt shows that the overlap of the global distribution of this species with the AoA is 0.17%. No comments were returned by the experts consulted.
Ara ararauna	**LC**	**EP**	Likely	The IUCN did not return any distribution of this species in Paraguay, but a broad distribution across the continent. GBIF shows all records from Paraguay either in Asuncion, or in the AoA. More information was requested from experts, but no comments were returned on this species
Ara chloropterus	**LC**	**EP**	Likely	The IUCN shows around 20% of the distributional range from Paraguay in the AoA, with GBIF showing more than 25% of the records within the AoA. Experts consulted did not provide any comments.
Cyanocorax cristatellus	**LC**	**AE**	Likely	IUCN shows more than 25% of the distribution of this species in Paraguay to be in the AoA. IBAT shows that the global distribution of this species presents an overlap of 0.22% with the AoA. Experts consulted did not provide any comments to the questions about this species.
Sporophila palustris	**EN**	**EP**	Likely	The IUCN shows that the AoA, and the northern part of the department of Amambay, are the only breeding areas for this full migrant species in Paraguay. The IUCN also shows a decreasing population, with 600-1700 mature individuals. Further investigation is required to confirm the presence of this species in the AoA. IBAT returned a 0.46% of overlap of the global distribution of this species with the AoA and included also under Criterion 1a to possibly qualify the AoA as Critical

				Habitat. Experts consulted did not provide any information on this species.
Alectrurus tricolor	**VU**	**EP**	Possible	IBAT showed more than 1% of the global population (1.43%) overlaps with the AoA. This is a full migrant species that lives in Brazil, Bolivia and Paraguay, and according to the IUCN map, this species is distributed in the AoA, and the AoA is a corridor between the border of the AoA with Brazil, and the rest of the population in Paraguay. Further investigations are required to confirm the presence of this species in the AoA. Experts did not provide any comments when consulted.
Amazona vinacea	**EN**	**EP**	Possible	Also assessed as possibly qualifying for CH under Criterion 1a, this globally endangered and nationally threatened species is likely to have a decreasing population, currently in the range of 1000-2499 mature individuals, and IBAT returns an Extent of Occurrence of 534683 km^2. The distribution range of the Vinaceous-breasted Amazon overlaps with the AoA, as shown by the IUCN Geographic range map. On the other hand, GBIF shows no occurrences in the AoA.
Laterallus xenopterus	**VU**	**AE**	Possible	IUCN and GBIF show a potential overlap of more than 20% of the distribution of this species in Paraguay with the AoA, further research is required to understand thet importance of the AoA for this nationally threatened species. Experts consulted did not provide any information on this species.
Mammals				
Ozotoceros bezoarticus	**NT**	**EP**	Likely	This species is present in other countries, but its entire distribution within Paraguay overlaps with the AoA. Experts consulted did not provide any information on this species.
Natalus stramineus	**LC**	**-**	Possible	The only record that GBIF shows in Paraguaya is in the AoA, and the IUCN only shows records in the Caribean. Gloria González de Weston (personal communication, 2nd of February) was consulted, and she explained that this species, included in the Red Book of Mammals of Paraguay with a degree of vulnerable, has a very limited distribution and very little is known about its biology, not only in Paraguay but also at the broader scale. She advised that the advance of the agricultural/livestock land in their range, subject their populations to a high level of pressure. More information is required to assess the likelyhood of this species for qualifying the AoA as Critical Habitat.
Priodontes maximus	**VU**	**EP**	Possible	The giant armadillo is an important species for conservation and present in the Ecoregion of Aquidaban (CSI Ingenieros, 2021). IBAT returned a 0.19% overlap between its global population and the AoA. IUCN maps show a broad distributional range at the continental level and in the Región Occidental of Paraguay. However, in the Región Oriental *Priodontes maximus* is only present in the AoA. No

				comments were received from the local experts with regards to this species.
Pteronura brasiliensis	**EN**	**EP**	Possible	A lack of data regarding this species does not show evidence of its presence within the AoA. However, GBIF shows one record across the Paraguay river, and IUCN shows that the species may be distributed along the border between the AoA and Brazil. Further information is required to confirm or discard the presence of this species in the AoA. Experts that were contacted did not provide any information on this species.

Criterion 2				
Taxon	IUCN status	National list	Category	Justification
Plants				
Opuntia stenarthra	**DD**	**-**	Possible	Ana Pin (personal communication, 18th of February) stated that this species, which can be found in forests and xerophytic shrubs in the AoA, is barely knonw, and there are very few botanical records. This is a DD species, with IBAT showing 100% overlap with AoA so more info needed
Trichocereus hahnianus	**DD**	**-**	Possible	IBAT returned a 100% overlap with AoA, with more information being needed. Ana Pin (personal communication, 18th of February, 2022) explained that there are very few botanical records; the first was collected in the vicinity of the Apa River, on "limestone rocks" (1937), which would be far from the properties, and the last was collected in the Chaco, about 100 km before reaching Philadelphia, published by Kiesling, R. et al (2020). Activities in the AoA could impact their populations if they still exist. This species can be found in the understory of the xerophytic forest.
Insects				
Ateuchus contractus	**DD**	**-**	Possible	IBAT showed a 58% overlap of the global distribution (1257km2) of this restricted range species with the AoA, and more information is required to understand if the species may be potentially present in the area. Experts were contacted but did not provide any information on this species.
Progomphus flinti	**DD**	**-**	Possible	IBAT returned a 46% overlap of the distribution of this species with the AoA, with a total range of 3293km2, and being Data Deficient, more information is needed. No comments were received from the experts consulted in regards to this species.
Amphibians				
Rhinella scitula	**DD**	**AE**	Possible	This species is Data Deficient (IUCN), and Hugo Cabral (personal communication, 20th of January) explained that this is a species associated with Cerrado environments, and endemic to the Cerrado of Brazil and Paraguay. Diego Bueno Villafañe (personal communication, 29th of January 2022) reported that this species is known in the Departments of Amambay, Concepción, and San Pedro, and he has found males, juveniles and metamorphs in riparian forests, both in the PARACEL properties, and in the Parque Nacional

				de San Luis, and not in other habitats. Hugo Cabral has found this species in the AoA and noted that this species is relatively common in its range. This species is not found in any other region of the country, which suggests this area as an endemic center for anurans in Paraguay (Cabral et al., 2020). The IUCN only shows distribution in a very small area of Brazil, near the border with Paraguay and the AoA. GBIF also shows 102 occurrences of this species in the same areas of Brazil. The information available therefore shows that the EOO of this species may be of less than 50,000km2, and it could possibly qualify the AoA as Critical Habitat.
Reptiles				
Amphisbaena albocingulata	**LC**	**-**	Likely	In a personal communication on the 20th of January 2022, Hugo Cabral noted that records of this species exist in Central and Paraguarí, and in Concepción, showing a disjunct distribution that attracts scientific interest. With the information available, it is understood that this species is endemic to Paraguay. Due to the fossorial habits of the entire genus makes these species difficult to find, so the little information available may be due to a lack of collection effort. IBAT returned an EOO of less than 50,000km2, and an overlap of 26% with the AoA, which could be more than 10% of global population.
Phalotris nigrilatus	**EN**	**EP**	Possible	This colubrid snake is endemic to San Pedro Department and is known from a very few historical specimens (Cacciali et al., 2020). Individuals are normally difficult to find. Being threatened, it obviously has conservation significance. (Hugo Cabral, personal communication, 20th of January 2022). More information is required to define a category other than Possible for this species.

Appendix 3: Historical Land Use – Land Cover analysis (1985-2021) methods description & maps

Land Use Land Cover (LULC) analysis forms the basis for the determination of CH for Criterion 4. Version 2 prepared 4th July 2022.

The Landcover maps for the project study area part of Concepción, Paraguay were created for the years 2021, 2001 and 1985. The classification consists of the following classes:

1) Natural forests
2) Waterbodies
3) Crops/Pastures/Foresty/other (includes agricultural land)
4) Savanna formations

The study used the Google Earth Engine Application Programming Interface[41] (GEE API) for the acquisition and analysis of remotely sensed data from Landsat missions. Boundary shapefiles were edited using QGIS version 3.20 and uploaded as assets to be used for clipping and masking operations in GEE.

The methodology and data sources used for deriving the above outputs are detailed below:

Landcover Maps

The classification of remotely sensed data has been achieved by using the Classifier package in the GEE API. This package uses different Machine Learning (ML) algorithms for supervised classification. For the current project, the Random Forest[42] algorithm has been used.

The general steps for classification are:

1. Creating an annual median composite of images by using filters for the date, cloud cover and the study boundaries. This composite image helps in removing cloud cover. For more refer Zhang (2021)[43] and Phan (2020)[44]
2. Adding bands to the collection of different spectral indices like the Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-up Index (NDBI) etc. and elevation and slope data from global elevation datasets
3. Creating training dataset using google earth base map and field data for reference
4. Splitting the training into validation and test for accuracy assessment
5. Running the Random Forest Classifier (Optimizing it by running iterations and finalising the number of trees=11)
6. Post-processing the output by running an unsupervised classification using the Image segmentation algorithm

[41] Gorelick, N. et al Google Earth Engine: Planetary-scale geospatial analysis for everyone, Remote Sensing of Environment, Vol 202, 18-27, (2017) ISSN 0034-4257, https://doi.org/10.1016/j.rse.2017.06.031.

[42] Breiman, L. Random Forests. Machine Learning 45, 5–32 (2001). https://doi.org/10.1023/A:1010933404324

[43] Zhang, Z et al. Assessment of Annual CompositeImages Obtained by Google Earth Engine for Urban Areas Mapping Using Random Forest. Remote Sens. (2021), 13, 748. https://doi.org/10.3390/rs13040748

[44] Phan et al. (2020). Land Cover Classification using Google Earth Engine and Random Forest Classifier – The Role of Image Composition. Remote Sensing. 10.3390/rs12152411, https://www.mdpi.com/2072-4292/12/15/2411

Output was exported and area calculations performed using zonal statistics in Q-GIS

The code for the above process has been adopted from Gandhi (2021)[45] and modified to suit objective of the study

Landcover Classification for 2021

Dataset: USGS Landsat 8 Level 2, Collection 2, Tier 1 [46]

Filters: Mask for Clouds and Shadows & Dates: '2021-01-01' to '2022-01-01'

A composite image with the following bands is created:

1. Sentinel-2 Bands: B1, B2, B3, B4, B5, B6, B7
2. Spectral Indices: NDVI, NDBI, Modified Normalized Difference Water Index (MNDWI), Bare Soil Index (BSI)
3. Elevation and Slope

Training data: Google Earth was used as a base map to check landcover classes.

Accuracy: Accuracy was calculated using a confusion matrix, and a test score of 73% was achieved

Link to code: **https://code.earthengine.google.com/dededed412a55c0bd3b8927c5ec54801**

Landcover Classification for 2001

Dataset: USGS Landsat 7 Level 2, Collection 2, Tier 1[47]

Filters: Mask for Clouds and Shadows & Dates: '2001-01-01', '2002-01-01'

A composite image with the following bands is created:

1. LANDSAT 7 Bands: B1, B2, B3, B4, B5, B7
2. Spectral Indices: NDVI, NDBI, MNDWI, BSI
3. Elevation and Slope

Training data: Google Earth was used as a base map to check landcover classes and training data for 2021 was edited to reflect the classes existing according to Landsat Red, Green, and Blue (RGB) composite created for 2001.

Accuracy: Accuracy was calculated using a confusion matrix, and a test score of 83% was achieved

Link to code: **https://code.earthengine.google.com/0a2316b4c53e5c4cc44b3c70f8892d34**

Landcover Classification for 1985

Dataset: USGS Landsat 5 Level 2, Collection 2, Tier 1

Filters: Mask for Clouds and Shadows & Dates: '1985-01-01', '1986-01-01'

For the provided study area the 1985 composite consisting of the following bands was created:

1. LANDSAT 5 Bands: B1, B2, B3, B4, B5, B7

[45] Gandhi, U End-to-End GEE, Spatial Thoughts Academy (2021), https://courses.spatialthoughts.com/end-to-end-gee.html#improving-the-classification

[46] https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/product-types/level-2a

[47] https://www.usgs.gov/core-science-systems/nli/landsat/landsat-collection-2-level-2-science-products

2. Spectral Indices: NDVI, NDBI, MNDWI, BSI
3. Elevation and Slope

Training data: Google Earth was used as a base map to check landcover classes and training data for 2001 was edited to reflect the classes existing according to the Landsat RGB composite created for 1985.

Accuracy: Accuracy was calculated using a confusion matrix, and a test score of 78% was achieved

Link to code: **https://code.earthengine.google.com/1601a6f5af9f87ea77689c15266d54c3**

Spectral Indices

The following spectral Indices have been used for improving the land cover classification:

- Normalised Difference Vegetation Index (NDVI)

  $NDVI = \frac{NIR-Red}{NIR+Red}$, Where NIR= Near Infrared band

- Normalised Difference Built-up Index (NDBI)

  $NDBI = \frac{SWIR-NIR}{SWIR+NIR}$, Where SWIR= Short wave Infrared Band and NIR= Near Infrared band

- The Modified Normalized Difference Water Index (MNDWI)

  $MNDWI = \frac{Green-SWIR}{Green+SWIR}$, Where SWIR= Short wave Infrared Band

- Bare Soil Index (BSI)

  $BSI = \frac{(SWIR2+Red)-(NIR+Blue)}{(SWIR2+Red)+(NIR+Blue)}$, Where SWIR= Short wave Infrared Band and NIR= Near Infrared band

The Vegetation Index or NDVI is an algorithm used to quantify the concentration of green-leaf vegetation or photosynthetically active biomass. This algorithm uses the Near-infrared (most reflected) and Red (most absorbed) wavelength of the light reflected from the earth surface and helps visualise vegetated areas and determine the health of the vegetation.

NDVI value varies from +1.0 to -1.0, where values below zero (0) represent landcover which is not vegetated, with sparse to dense vegetation ranging from +0.2 to +1.

Accuracy Calculations

For accuracy assessment, the training samples (Ground control Points) were split into random fractions (80:20)- 80% of them used for training the model and the remaining 20% for validation. The classified image values were compared with the validation fraction values using a confusion matrix that represents the expected accuracy. However, this accuracy indicative of the quality of the training samples selected for generating the land use and not necessarily the indicator of how accurate the classification is with respect to the actual landcover. The accuracy percentage for each classification is tabulated below:

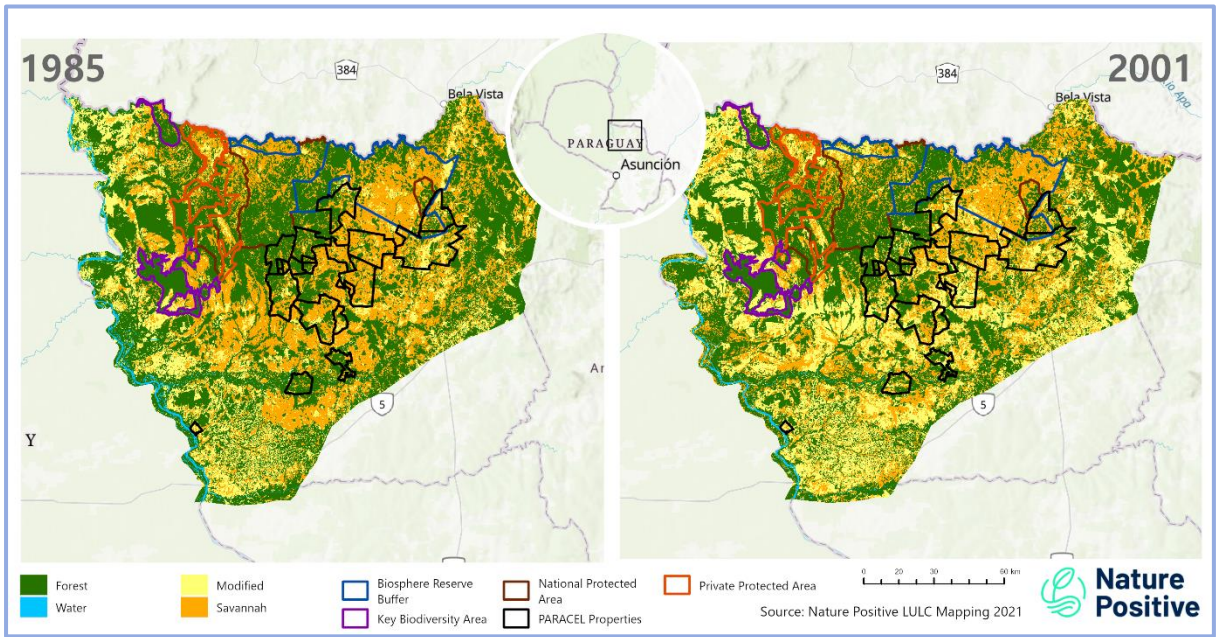
Year	Accuracy (%)
1985	78
2010	83
2021	73

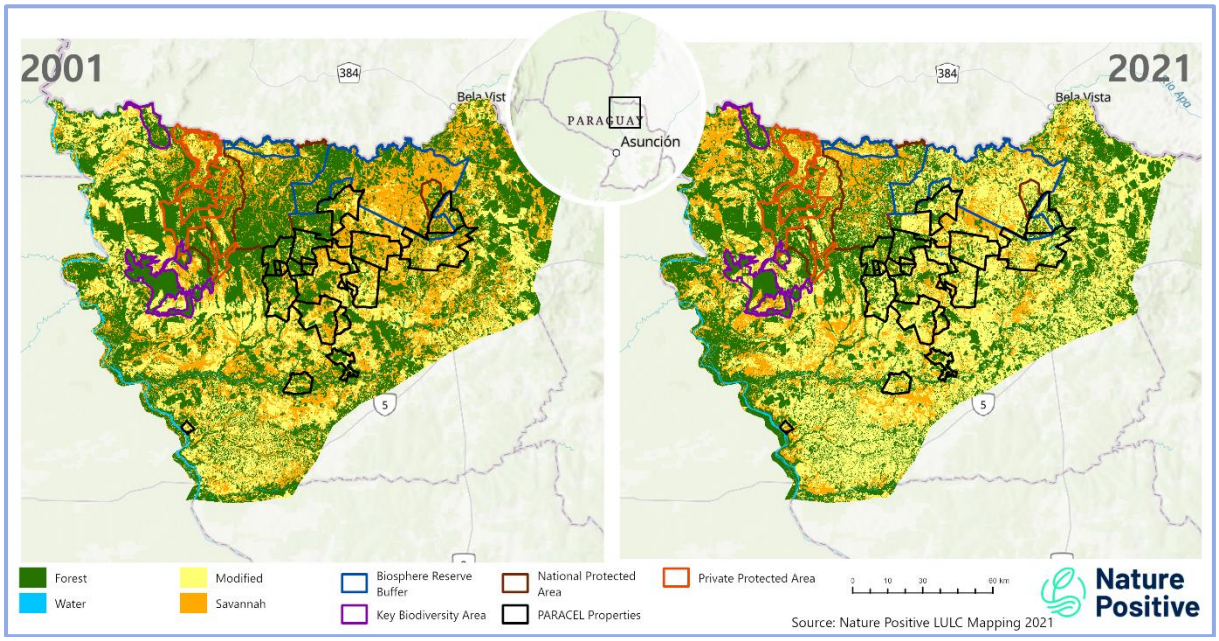
Limitations

The images used for 1985 and 2001 will be of a lower resolution and include fewer spectral bands as those of 2021 so the historical landcover mapping was not as accurate as for 2021.

Ground reference data was applied only for the Classification of 2021 image. Validations for earlier periods was based on visual inspection of RGB composite imagery for the period.

Output Summary Maps



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