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Botanical survey to identify Saldanha Limestone Strandveld on farms Yzerfontein 560 (partly), Tygerfontein 564, Coffee Fontein 563, Plot 2717, and the green corridors within Yzerfontein, Western Cape

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PREPARED FOR
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Executive Summary

This report details a botanical survey on farms Yzerfontein 560 (partly), Tygerfontein 564, Coffee Fontein 563, Plot 2717, and the green corridors within Yzerfontein, Western Cape (the study area). Specific focusing was given to detecting and delineating the critically endangered vegetation type Saldanha Limestone Strandveld (FS 4) and its associated plant communities, with an additional, though lesser focus, on delineating other vegetation types.

The study identified five primary VegMap vegetation types: Hopefield Sand Fynbos, Langebaan Dune Strandveld, Saldanha Flats Strandveld, Saldanha Limestone Strandveld, Saldanha Granite Strandveld.

A total of 156 plant species were recorded during the surveys, with 19 identified as Species of Conservation Concern (SCC). Among these, 10 are threatened (Critically Endangered, Endangered, or Vulnerable). The delineation of vegetation types was achieved through a combination of on-site surveys (85 km traversed on foot and by vehicle, 59 plots surveyed), drone reconnaissance, the use of indicator plant species, and GIS modelling.

Vegetation plot cluster analysis revealed six distinct vegetation clusters, broadly categorized into valley bottom strandveld, sand fynbos, strandveld thicket, and three variations of Saldanha Limestone Strandveld, or “limestone vegetation” (coastal backdune, coastal seafront, and inland). The predictive GIS model for Saldanha Limestone Strandveld demonstrated a high overall balanced accuracy of 83.69%, with a strong specificity (0.9807), prioritizing the identification of true positive Saldanha Limestone Strandveld areas due to its critically endangered status.

Ultimately, 48 natural Saldanha Limestone Strandveld fragments were delineated, totalling approximately 55.88 hectares. The vast majority, 54.11 hectares, are in pristine condition, with only minor areas exhibiting slight (0.16 ha) or moderate (1.61 ha) degradation. These fragments, particularly the inland limestone “islands” and coastal seafront limestone units, exhibit a very high conservation value due to their unique species composition and the presence of numerous SCC. The study also noted areas of disturbance, including previously ploughed lands and invasive alien plant species, on certain farms within the study area.

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PART 1: Introduction and Background Information

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1. Introduction

1.1. General Information

This project, as well as any and all related areas/sites, will from here on interchangeably be referred to as either the "Project", "Project Area", "study area", or "study area and surrounds". Furthermore, the term "vegetation type" is not necessarily used in the strict sense according the official National Vegetation Map of Southern Africa, Lesotho, and Swaziland (Mucina & Rutherford, 2006) with subsequent updates (Dayaram et al., 2018). Instead, it is used more generally to indicate distinct vegetation units within the current landscape that may be identified with reasonable ease, and might thus be more site specific.

Jos de Villiers Belleggings Trust (hereafter referred to as the "client") approached EcoFloristix Specialist Botanical Surveys to conduct a Botanical survey to identify Saldanha Limestone Strandveld on farms Yzerfontein 560 (partly), Tygerfontein 564, Coffee Fontein 563, Plot 2717, and the green corridors within Yzerfontein, Western Cape.

1.2. Terms of Reference (ToR)

The main aim of this assessment was to provide a professional opinion on botanical matters of the study area, but with a specific focus on surveying for Saldanha Limestone Strandveld (FS 4) as defined by the National Vegetation Map of Southern Africa, Lesotho, and Swaziland (Mucina & Rutherford, 2006) with subsequent updates (Dayaram et al., 2018).

Briefly, the following activities were to be conducted:

- Fieldwork, focusing on determining the presence of Saldanha Limestone Strandveld on:
    - Farm Coffee Fontein RE/563
    - A Portion of Farm Yzerfontein 560(4)
    - Yzerfontein "Green" Corridors, with erf numbers 578, 658, 945, RE/1003, 1480, 1772, 1480, 1580, 1548, 1710 and 1931.
    - Farm Tygerfontein 25/564.
    - Plot 2717.

1.3. Locality Details

The study area is located in and around the small town of Yzerfontein, Western Cape (Map 1). Specifically, the farms Coffee Fontein RE/563, Tygerfontein 25/564, and Yzerfontein 560 are located to the east and southeast of Yzerfontein, with Tygerfontein 25/564 and Yzerfontein 560 directly bordering the urban fringe (that is, the built-up urban edge) of Yzerfontein. The so-called green corridor is located within Yzerfontein and stretches for about 4 km in a southeastern to northwestern direction. Plot 2717 borders the R315 road near the entrance of the town Yzerfontein.

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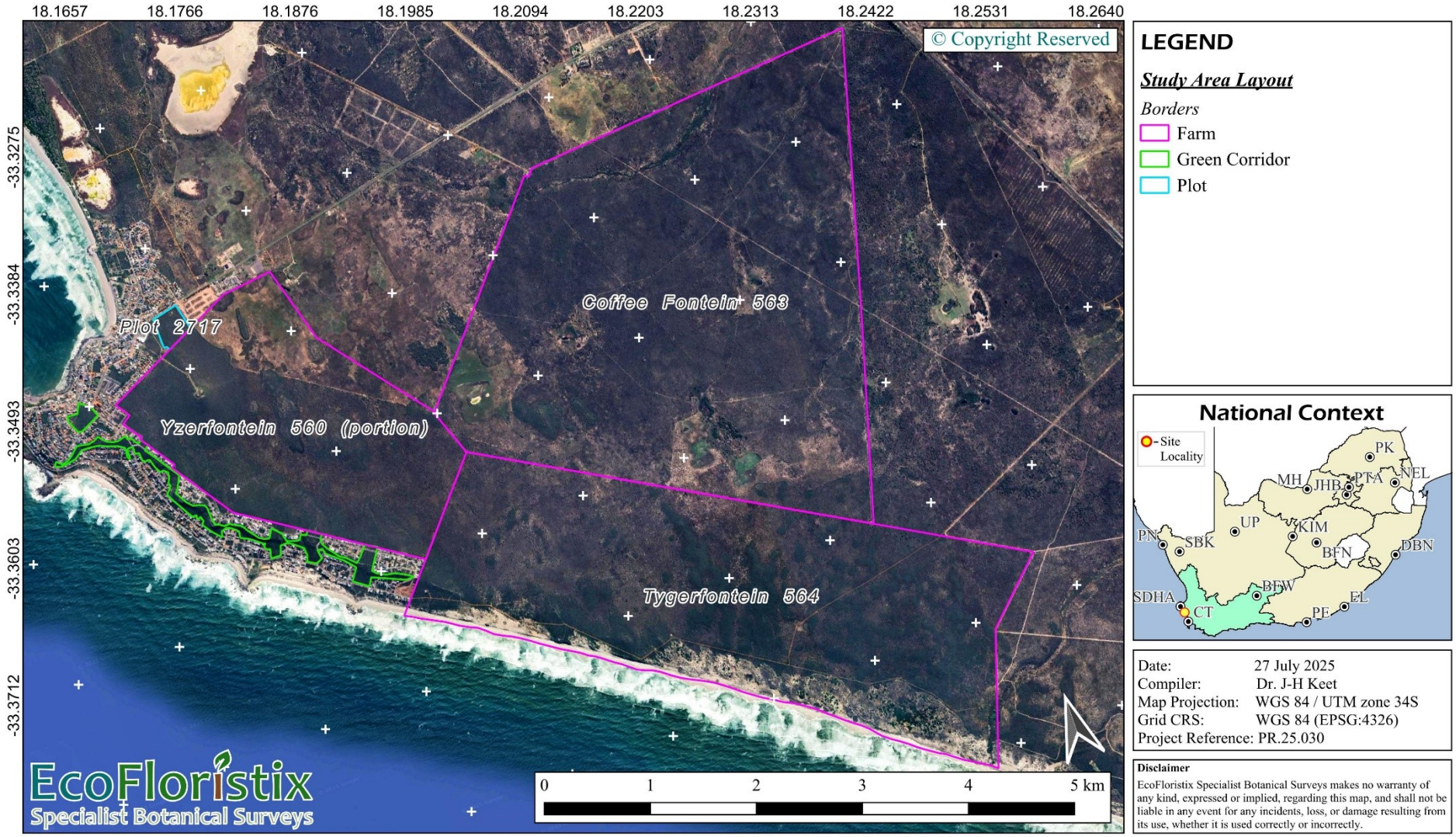

Map 1: Layout of the study area, zoomed out to give a broad context. The inset map shows the main map extent within the broader (national) context of South Africa. Note that, to optimize space, true north faces slightly to the top left.

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1.4. Conditions of This Report

This report deals exclusively with the study area as defined in sections 1.1 and 1.3, and the plant diversity and natural ecosystems in that area. Therefore, all relevant project information provided by the client to the biodiversity specialist was assumed to be correct and valid at the time of its provision. This report is not liable to include and assess any alterations to the study area, if such alterations occurred after the survey date(s).

All findings, recommendations, and conclusions provided in this report are based on the author's best scientific and professional knowledge at the time of compilation, as well as information available at the time of compilation. This report, whether in full or in part, may not be amended or extended in any way whatsoever without the prior explicit written consent of the author. Any recommendations, statements, or conclusions drawn from, or based on, this report must clearly cite or make reference to this report, making sure to include the following reference: PR.25.030. This report must be included in its entirety whenever any recommendations, statements, or conclusions relating to this report form any part of another report.

1.5. General Assumptions and Potential Limitations

Temporal variation plays an important role in the structure and patterns of plant biodiversity, communities, and species occurrences. One site visit (or even multiple visits), or a single season's survey, might not fully catalogue plant species diversity in an area (for example, due to seasonal variation in vegetation and plant growth patterns).

Specifically, some annual, short-lived, ephemeral (plants surviving unfavourable conditions as seeds), geophytic (species with underground storage organs), or other cryptic species might not be observable/detectable. That is, many plant species are known to completely die back during certain times of the year, depending on their respective life strategies. Thus, during these times such species remain unobservable/undetectable and survive only as dormant bulbs, corms, tubers, or rhizomes (for geophytes), or seeds (for ephemeral species) below the soil surface. Together with this, rare and threatened plant species are generally uncommon and/or localized, and can easily be overlooked. Even multiple site visits might fail to locate such species.

Furthermore, flowers and fruits are crucial for the complete and accurate identification of plant species, and any absence of such flowers and fruits might prevent the complete and accurate identification of such plant species. Flowering and fruiting times are species specific, and there are invariably always some plant species not flowering and/or fruiting during surveying. This not only impacts identifiability, but also detectability/visibility.

Finally, in practice it is almost always impossible to survey any area to its full extent, both spatially (i.e., over land surface area) and temporally (i.e., over time). The total number of plant species recorded in any area is, therefore, almost always an underestimate of the potential number of species that could occur in such an area.

Considering all of the aforementioned, the possibility always exists that certain plant species might not be observable/detectable on site during the time of surveying, as a result of their potential annual, short-lived, dormant, cryptic, or ephemeral nature, or their rare and/or localized distributions on site, or the incomplete and inaccurate identification of plant species which lacked flowers and/or fruits and/or other characteristic features during surveying. This presents a gap in knowledge, but can be mitigated to a great extent by supplementing site species lists with records from online databases.

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2. Background Assessment

For all relevant methodology, see sections 7 and 8 at the end of this document.

The study area is situated within the Fynbos biome and the Cape Floristic Region (CFR; also known as the Core Cape Subregion or CCR), a globally significant biodiversity hotspot. The CFR is the smallest floristic region worldwide but boasts an extraordinary diversity of plant species, with a high proportion of endemic species (those found nowhere else) (Goldblatt & Manning, 2002; Manning & Goldblatt, 2012). The southwestern Cape, in particular, is a national and global conservation priority due to the concentration of plant Species of Conservation Concern (SCC), many of which are endangered by habitat loss from agriculture, urbanization, and/or alien invasive plants.

The Yzerfontein area is considered a southern extension of the Langebaan and Saldanha region, sharing similar vegetation types and plant species. The Langebaan, Saldanha, and Yzerfontein regions have undergone rapid urban development, leading to significant pressure on their natural vegetation communities, which are known for having high numbers of SCC, as well as endemic plant species.

Despite many updates and refinements to the National Vegetation Map of South Africa (or VegMap for short), many areas, including Yzerfontein and its surrounds, remain coarsely mapped regarding vegetation patterns.

2.1. Vegetation Types of the Study Area

According to VegMap, the study area overlaps mainly with three vegetation types, namely Hopefield Sand Fynbos (FFd 3), Langebaan Dune Strandveld (FS 5), and Saldanha Flats Strandveld (FS 3; Map 2). Swartland Granite Renosterveld also occurs to the east of the border of farm Coffee Fontein RE/563 and Atlantis Sand Fynbos (FFd 4) to the east of farm Tygerfontein 25/564. Also, a small part of Cape Seashore Vegetation (AZd 3) is mapped for the study area and coincides with dune vegetation directly bordering the ocean.

As mentioned, Yzerfontein and its surrounds remain coarsely mapped regarding vegetation patterns and Saldanha Limestone Strandveld (FS4) has not been specifically mapped for this region by VegMap. However, it has been known to occur in the area for quite some time. Another vegetation type that is not currently mapped, namely Saldanha Granite Strandveld (FS), has also been detected previously (Helme, 2008).

Brief notes regarding these vegetation types are:

- Langebaan Dune Strandveld: generally occurs on alkaline sands along the coast.
- Saldanha Flats Strandveld: typically found in low-lying sandy flats between coastal dune strandveld and inland sand fynbos.
- Hopefield Sand Fynbos: occurs on acid sands and is characterized by deep sandy soils.
- Saldanha Limestone Strandveld: found specifically on exposed limestones or calcretes that have a very shallow soil bank; typically found in higher lying areas.
- Saldanha Granite Strandveld: restricted to granites and granite-derived soils.

Saldanha Limestone Strandveld is currently listed as Critically Endangered by the Red List of Ecosystems database.

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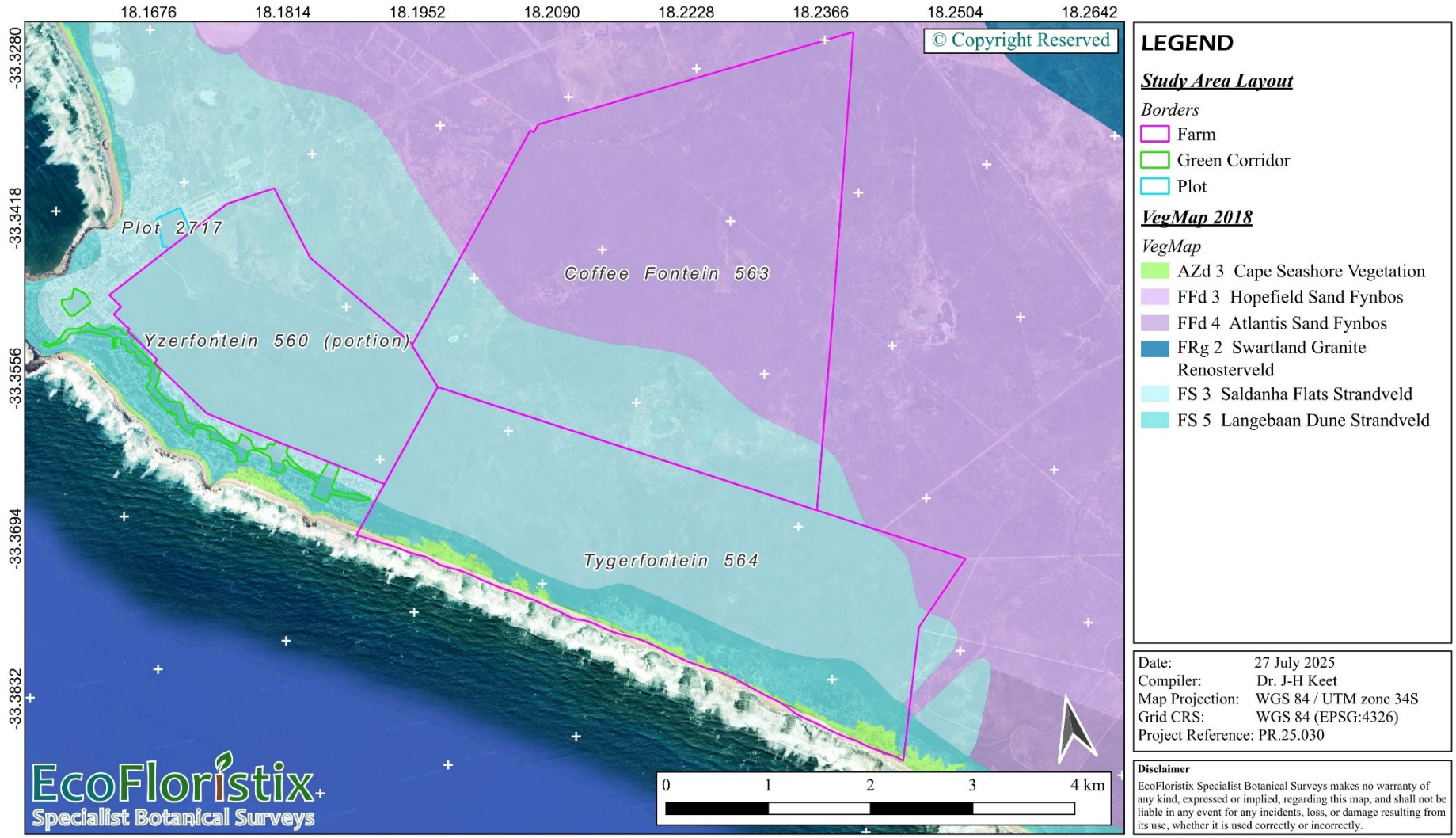

Map 2: Vegetation types (according to VegMap 2018 and subsequent updates) for the study area and surrounds.

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2.2. Saldanha Limestone Strandveld Indicators

Delineating vegetation types accurately presents a fundamental challenge in ecological research and land management. The natural world rarely conforms to rigid boundaries, instead often exhibiting gradual transitions or ecotones where different plant communities merge. This inherent continuum of vegetation, driven by often subtle shifts in environmental factors like soil, hydrology, and microclimate, complicates the creation of definitive boundaries.

Nevertheless, a few techniques aid in this delineation, which include the use of indicator plant species (also see section 7.3 regarding specific GIS methods employed in this study). These are specific plant species whose presence and abundance are usually strongly associated with particular environmental conditions, and thus vegetation types (an excellent example lies in aquatic species adapted to wetland conditions where they are abundant, but which are completely absent in non-wetland habitats).

However, the utility of indicator species is not without limitations. A key challenge arises from the fact that many "indicator" species often are not exclusive/endemic to a single vegetation type. While they might thrive and be most abundant in a particular environment, they can sometimes occur elsewhere, albeit in lesser numbers or under suboptimal conditions. Moreover, they also often occur in so-called transition zones or ecotones (where one vegetation type gradually merges with another) and their mere presence in such zones do not by default qualify these areas as being the vegetation type in which the indicator is usually found. Therefore, while highly useful, indicator species must be used in conjunction with other ecological data and expert knowledge to achieve more accurate and robust vegetation delineations.

According to VegMap a few plant species are endemic to Saldanha Limestone Strandveld, and would thus theoretically be excellent indicators. They are: *Muraltia harveyana*, *Cephalophyllum rostellum*, *Felicia elongata*, *Limonium acuminatum*, *Manulea augei*, *Daubenya zeyheri*, *Gladiolus caeruleus*, *Ixia purpureorosea*, *Moraea calcicola*, and *Romulea barkerae*. Furthermore, some other Biogeographically Important Taxa (all West Coast endemics) are: *Limonium capense*, *Asparagus capensis* var. *litoralis*, *Zaluzianskya parviflora*, and *Thamnochortus spicigerus*.

Together with this, a few other plant species not explicitly mentioned as endemic to Saldanha Limestone Strandveld are known to be characteristically found in limestone substrates with shallow soils. These include *Agathosma thymifolia*, *Diosma guthriei*, *Lessertia tomentosa*, and *Nenax hirta* subsp. *calciphila*.

Thus, the following species (which were specifically detected on site) were used to aid the delineation of Saldanha Limestone Strandveld and associated variations:

- *Agathosma thymifolia*
- *Diosma guthriei*
- *Gladiolus caeruleus*
- *Lessertia tomentosa*
- *Limonium acuminatum*
- *Muraltia harveyana*
- *Nenax hirta* subsp. *calciphila*

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Although *Gladiolus caeruleus* is indicated as being endemic to Saldanha Limestone Strandveld, it can be, and indeed in this study was, found in deep alkaline sands overlying limestone instead of typical shallow soils with exposed calcretes, which is why it might rather be considered a secondary indicator. The same goes for *Nenax hirta* subsp. *calciphila* (not to be confused with *Anthospermum spathulatum* which it resembles and which occurs in the area) in that it mostly occurs overlying limestone but often occurs abundantly in transition zones. Finally *Lessertia tomentosa* is known for not only occurring on shallow limestones, but is nevertheless useful.

It must be noted that numerous other, often common, plant species are also associated with Saldanha Limestone Strandveld, and might even be abundant in such areas (for example, *Euclea racemosa*, *Roepera* species, *Searsia glauca*, *Chrysanthemoides monilifera*). However, their occurrence in these and other similar areas are more correlated with shallow substrates, which can be derived from a geology other than limestone, and they are thus widespread in the area where similar environmental conditions occur. Their presence does not by default indicate Saldanha Limestone Strandveld, and in fact often complicates classification given that they are shared between other vegetation types.

Finally, regarding substrates: more typical Saldanha Limestone Strandveld is characterized by shallow soils overlying hardpan tertiary limestone with an abundance of calcrete rocks (easily identified by its white-grey colouring), which characteristically leads to a more open vegetation cover and structure.

Thus, in addition to the use of various GIS layers (with subsequent modelling) and aerial photography, the delineation of Saldanha Limestone Strandveld was done using a combination of indicator plant species (especially when many of them co-occured) and the presence of shallow soils with an abundance of calcrete rocks (see Figure 1).

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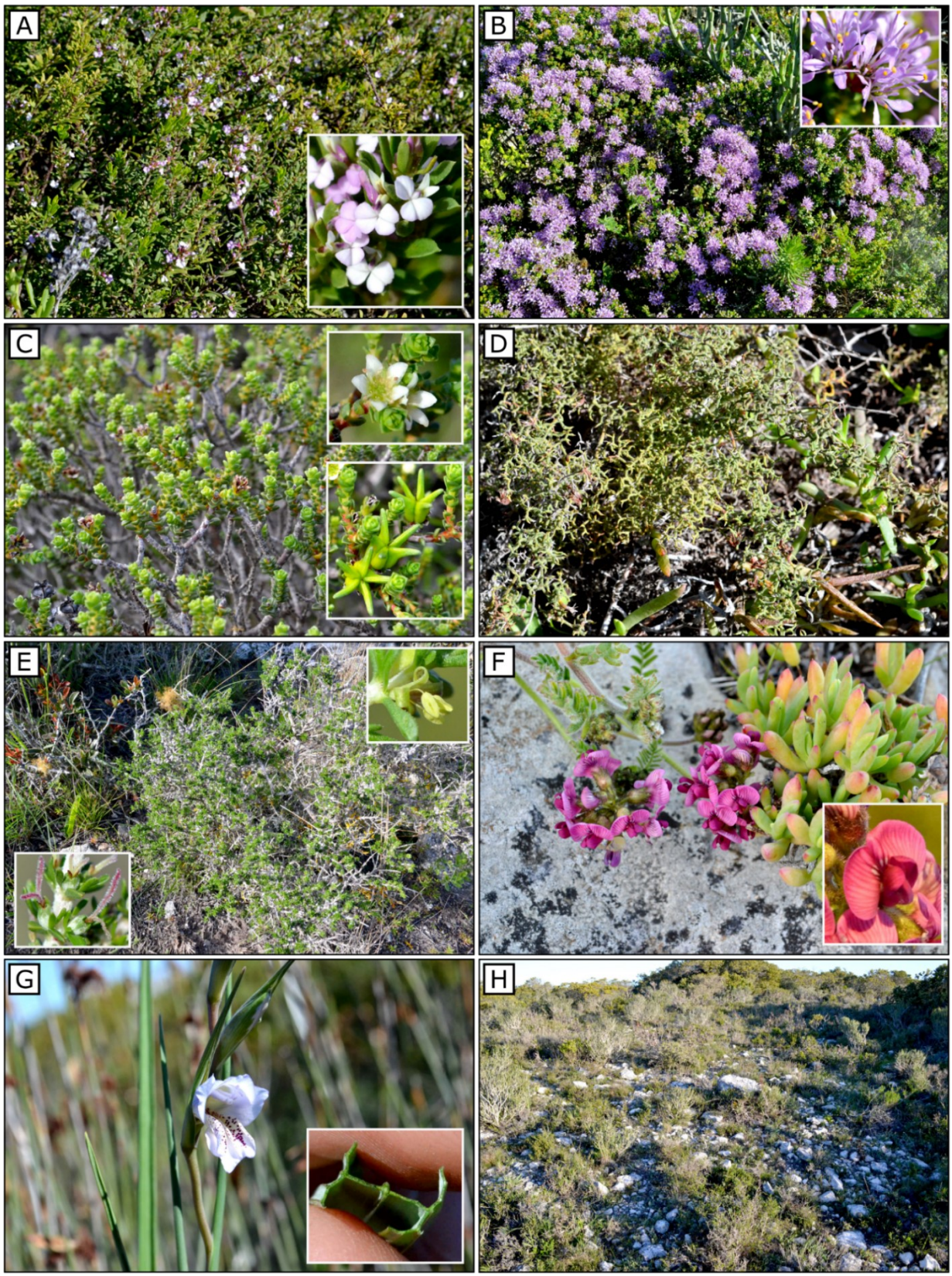

Figure 1: Limestone indicator plant species for Saldanha Limestone Strandveld: A) *Muraltia harveyana*, B) *Agathosma thymifolia*, C) *Diosma guthriei*, D) *Limonium acuminatum*, E) *Nenax hirta* subsp. *calciphila* (male and female flowers indicated separately), F) *Lessertia tomentosa*, and G) *Gladiolus caeruleus* (showing leaf that is characteristically H-shaped in cross-section). H) Typical example of a limestone outcrop with shallow soils, abundance of calcrete rocks, and an open vegetation structure.

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PART 2: Findings of the Botanical Survey

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3. Fieldwork and Site Inspection

The botanical survey was conducted on 15 – 18 July and 22 – 23 July 2025. This timeframe falls slightly outside the optimum surveying period (which is generally accepted to be during spring and the beginning of summer; also see section 1.5 for assumptions and potential limitations). However, the vegetation was in a relatively good condition for surveying. Moreover, the primary plant species indicators for Saldanha Limestone Strandveld (section 2.2) were easily observed since they are all shrubby species that were either fully or at least partly in flower (with the exception of *Limonium acuminatum*, though it was still observable).

A total distance of ± 85 km was surveyed across the study area on foot and by vehicle. Together with this, numerous drone reconnaissance trips were made to gain locality data and insights on areas that potentially have shallow soils with an abundance of calcrete rocks and open vegetation structure.

A total of 59 plots were surveyed across the study area, with a specific focus on the vegetation occurring in the green corridor and near the coast (the vegetation inland eventually changes to sand fynbos, and while it was surveyed and included in the results, it was not a major focus of this study).

These field observations combined with the GIS modelling and cluster analysis of vegetation plots has yielded results with a high degree of confidence regarding the presence of Saldanha Limestone Strandveld.

Note that, to optimize space, in many of the maps that follow true north does not face directly to the top.

3.1. Plant Species Occurrences and Species of Conservation Concern

A total of 156 plant species were recorded during the surveys of the study area. This is a significant amount for such a short period or surveying, given that iNaturalist (a popular online citizen science platform) records for the area total just under 320 species (when filtering "Research Grade" quality records).

The most commonly recorded species were *Asparagus capensis* var. *litoralis*, *Euclea racemosa* subsp. *racemosa*, *Euphorbia burmannii*, *Limonium peregrinum*, *Nenax hirta* subsp. *calciphila*, *Osteospermum moniliferum* subsp. *moniliferum*, *Pteronia divaricata*, *Putterlickia pyracantha*, and *Searsia glauca*. Each of these species occurred in more than half of all the plots.

Furthermore, a total of 19 Species of Conservation Concern (SCC) were recorded, 10 of which are threatened (i.e., have an IUCN redlist status of Critically Endangered, Endangered, or Vulnerable). These are listed in Table 1. Most of these SCC occur within Saldanha Limestone Strandveld vegetation or sand fynbos (specifically the Hopefield Sand Fynbos areas within the study area). Furthermore, while their general localities are given by Map 3, it should be noted that not every single individual of each plant SCC were recorded (which would be near impossible for those that occur in large abundances). Their localities are thus intended to serve as a general guide only.

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Table 1: Plant Species of Conservation Concern that were recorded within the study area. They are listed in order of decreasing threat status.

Plant Species	IUCN
Amphithalea ericifolia subsp. erecta	CR
Erica bolusiae var. bolusiae	CR
Indigofera platypoda	EN
Agathosma thymifolia	VU
Cheiridopsis rostrata	VU
Leucadendron cinereum	VU
Limonium acuminatum	VU
Muraltia harveyana	VU
Nenax hirta subsp. calciphila	VU
Restio impolitus	VU
Aspalathus ternata	NT
Asparagus lignosus	NT
Diosma guthriei	NT
Freesia viridis subsp. viridis	NT
Gladiolus caeruleus	NT
Lessertia tomentosa	NT
Leucospermum tomentosum	NT
Serruria decipiens	NT
Ruschia umbellata	DDT

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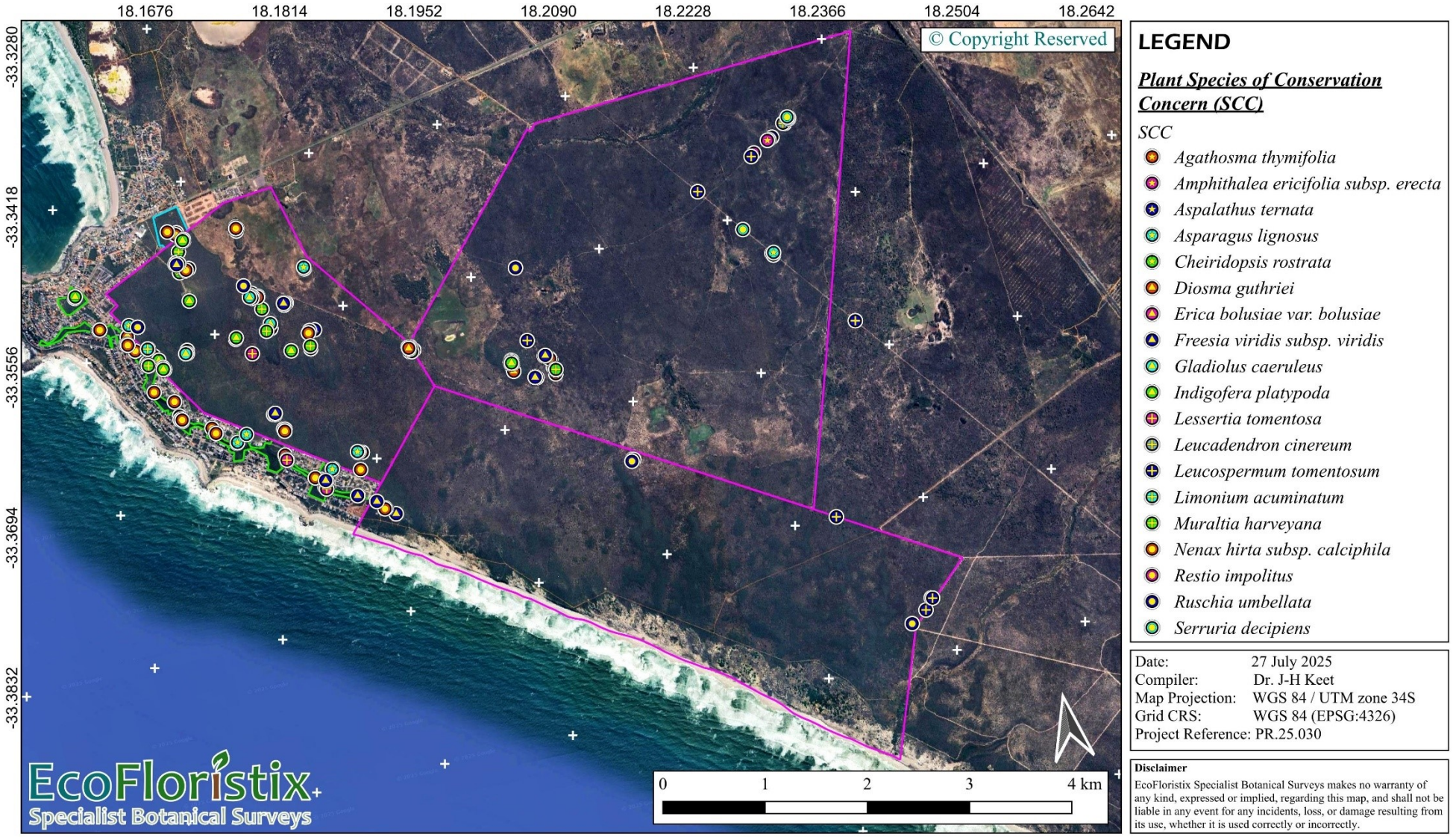

Map 3: Localities and identities of plant Species of Conservation Concern that were recorded during the surveys.

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3.2. Clustering of Vegetation Survey Data

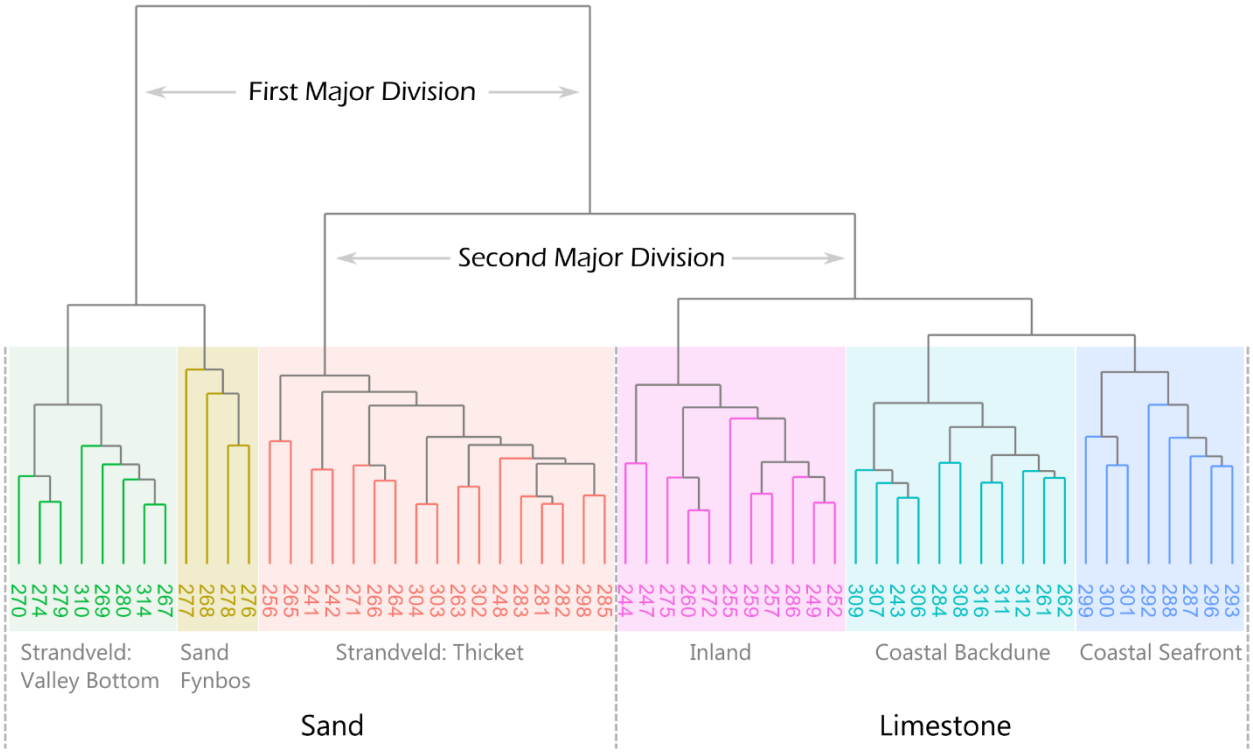

Figure 2: Cluster dendrogram of the vegetation survey data. It illustrates the hierarchical relationships among the various vegetation plots (indicated by numbers) that were sampled in this study (see Map 3 for plot localities). Plots are grouped based on their similarity in species composition and cover. The dendrogram's "branches" show how plots or clusters are fused together, with the height of each fusion indicating the dissimilarity between the merged groups. Taller branches signify greater species composition differences, which aids in identifying natural groupings or communities within the vegetation data.

Based on a clustering of the vegetation survey data (see section 7.1 for methods), six distinct clusters could be identified (Figure 2; Map 4 and Map 5). The first major division occurs between valley bottom strandveld and sand fynbos (to the northeast of the study area, specifically on farm Coffee Fontein RE/563, as well as partly on Tygerfontein 25/564), and strandveld thicket and limestone vegetation.

Although the term valley bottom strandveld is not an official VegMap term, it is used here in a general sense to refer to all the low-lying areas close to the coast that are dominated by restios (Cape reeds), such as *Willdenowia incurvata* (Sonkwasriet). Although these vary somewhat in composition, it is doubtful whether they should be considered as variations of Saldanha Flats Strandveld (FS 3) as mapped and described by VegMap given the dominance and extremely high abundance of *Willdenowia incurvata*. In this regard, it is actually more similar to Langebaan Dune Strandveld (FS 5), but should likely be considered a vegetation type in its own right. This is why it is preferred to refer to it here as valley bottom strandveld. In contrast, the sand fynbos areas conform to Hopefield Sand Fynbos (FFd 3).

This major division is not at all surprising given that the valley bottom strandveld and sand fynbos areas are characterized by a dominance of restios, which are almost completely absent in the thickets (occurring mostly on sandy dune plumes) and limestone vegetation (areas with shallow soils and an abundance of calcrete rocks). Thus, although their underlying geologies differ (sand fynbos is acidic while the valley bottom strandveld is alkaline), their dominant species makeup have

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more similarities with each other than with the limestone units and thickets. The valley bottom strandveld and sand fynbos units are themselves further divided into distinct and separate clusters based on a few characteristic dominant and rare species. For example, the sand fynbos units were characterized by *Leucospermum tomentosum*, *Thamnochortus punctatus*, and *Willdenowia sulcata*, while valley bottom strandveld was characterized mostly by *Willdenowia incurvata*. Other, rarer species present in the sand fynbos units included *Erica lasciva*, *Leucadendron salignum*, *Serruria decipiens*, *Staavia radiata*, and *Stilbe ericoides*, which were absent in the valley bottom strandveld.

The second major division occurs between the strandveld thicket and limestone units. Again, the term strandveld thicket is not an official VegMap definition, and is used here to refer generally to raised dunes characterized by a dense thicket-like vegetation and deep, sandy soils, and can be considered as part of Langebaan Dune Strandveld. These strandveld thicket units differ from the valley bottom strandveld and sand fynbos units in that they have more thicket-like plant species in common with the limestone vegetation. This is why these units integrate easily with Saldanha Limestone Strandveld and its variations given that it is often a matter of soil depth that separates these. This can especially be seen in the main ridge behind the urban fringe as well as the green corridor where the strandveld thicket often alternates with coastal seafront limestone vegetation. Thus, it is not at all surprising that it shares the majority of plant species with the limestone vegetation units, and even many of the dominant species (though it did have a few species found within it that were almost absent in the limestone units, such as *Lycium ferocissimum*, *Pteronia onobromoides*, and *Thamnochortus spicigerus*). Therefore, regarding differences between strandveld thicket and the limestone vegetation units, a key distinguishing factor is firstly the virtual absence, or very rare occurrences, of key limestone indicator plant species (see section 2.2). Secondly, quite a number of species were found in the limestone units that were completely absent from the strandveld thicket units. These included *Agathosma serpyllacea*, *Euryops linifolius*, *Lessertia tomentosa*, *Massonia longipes*, *Melolobium exudans*, and *Pteronia uncinata*. These are not limestone indicators *per se*. However, they are prone to occurring in shallower soils instead of deeper, sandier soils, and thus in this context serve to indicate a transitioning from the deeper sands of the dunes toward shallower soils that eventually culminate in the characteristic limestone benches of Saldanha Limestone Strandveld.

Finally, three clusters that characterize limestone vegetation were found. For the purposes of this context, they are called coastal backdune limestone, coastal seafront limestone, and inland limestone vegetation. All of these can be considered as variations of Saldanha Limestone Strandveld. Their differences are more subtle than the other divisions, and they share many of the same species. Nevertheless, they still differ in a few key ways. Chief among these includes the influence of the ocean and its resultant salt sprays, giving rise to coastal seafront limestone. These harsh conditions influence the dominance and cover of many of the species. Also, the coastal seafront limestone vegetation had a few limestone indicators that were either completely absent in the backdunes, such as *Agathosma thymifolia* and *Diosma guthriei*, or almost completely absent, such as *Muraltia harveyana*. Furthermore, *Lessertia tomentosa* did not occur in the coastal backdune limestone plots. Similarly, some species occurred in the backdunes that were absent near the ocean side, such as *Agathosma imbricata*, or were more dominant, such as *Euphorbia burmannii* and *Pteronia divaricata*.

Finally, the inland limestone units had the majority of species in common with the coastal backdune limestone and coastal seafront limestone units. These inland limestone units are characterized by distinct transitional zones around their borders that merge with the surrounding low-lying valley bottom strandveld where the restio *Willdenowia incurvata* dominates. These transition zones are important ecotonal areas; however, they should not be considered as true Saldanha Limestone Strandveld.

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All of the limestone units characteristically occur in areas with shallow soils and often exposed shelves of limestone, or which at least have a high abundance of calcrete rocks.

It must be noted that while cluster analysis excels at identifying different vegetation patterns, it is not without its drawbacks. Plots can, and indeed do, get grouped with vegetation types they do not truly belong to. This can happen because of outlier or transitional plots that share just enough characteristics with a different type to be pulled into its cluster. An example of this can be seen with plot 286 that was grouped with the inland limestone units, but is clearly part of the coastal seafront limestone area. Similarly, plot 263 occurs in a limestone ridge, but is classified with the strandveld thicket units. Plots 248 and 256 are clearly part of the inland limestone units since they occur in distinct limestone outcrops, but were classified as strandveld thicket. However, the outcrop where plot 256 occurs is very degraded, which heavily influenced its grouping. Subtle or continuous differences between vegetation types likely contributed just enough in some of these instances to cause a few misclassifications. Finally, plot 308 was classified as coastal backdune limestone but was clearly not typical of Saldanha Limestone Strandveld, as can been seen by photo S12 (Figure 6) in section 3.4. Despite this, these instances should not detract from the overall usefulness of the classification, and such minor errors is exactly why other supplementary methods (GIS modelling and environmental characteristics) are used in conjunction with the classification to aid in the delineation of different vegetation types.

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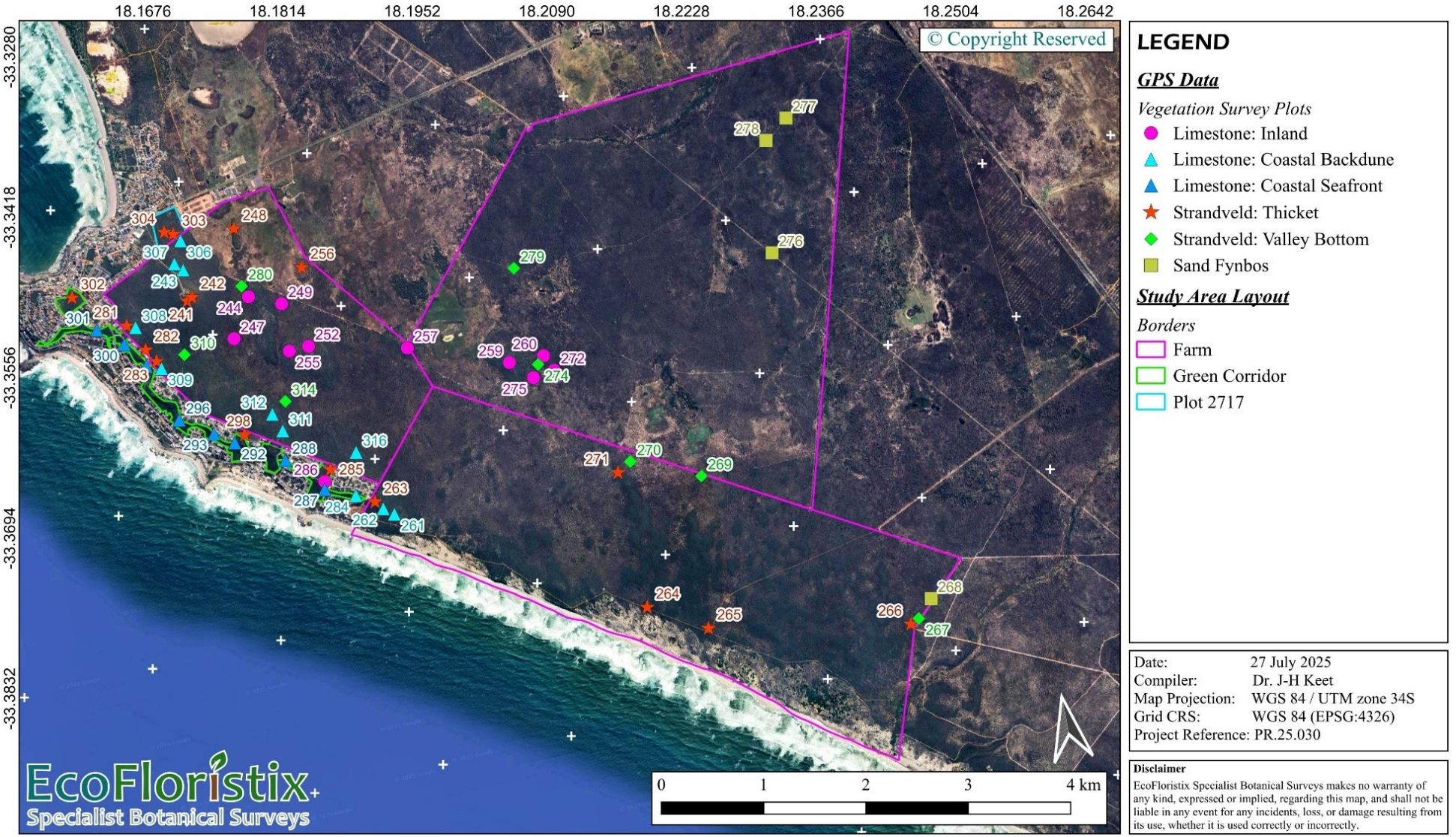

Map 4: Localities and classification of the various vegetation plots that were surveyed during this study.

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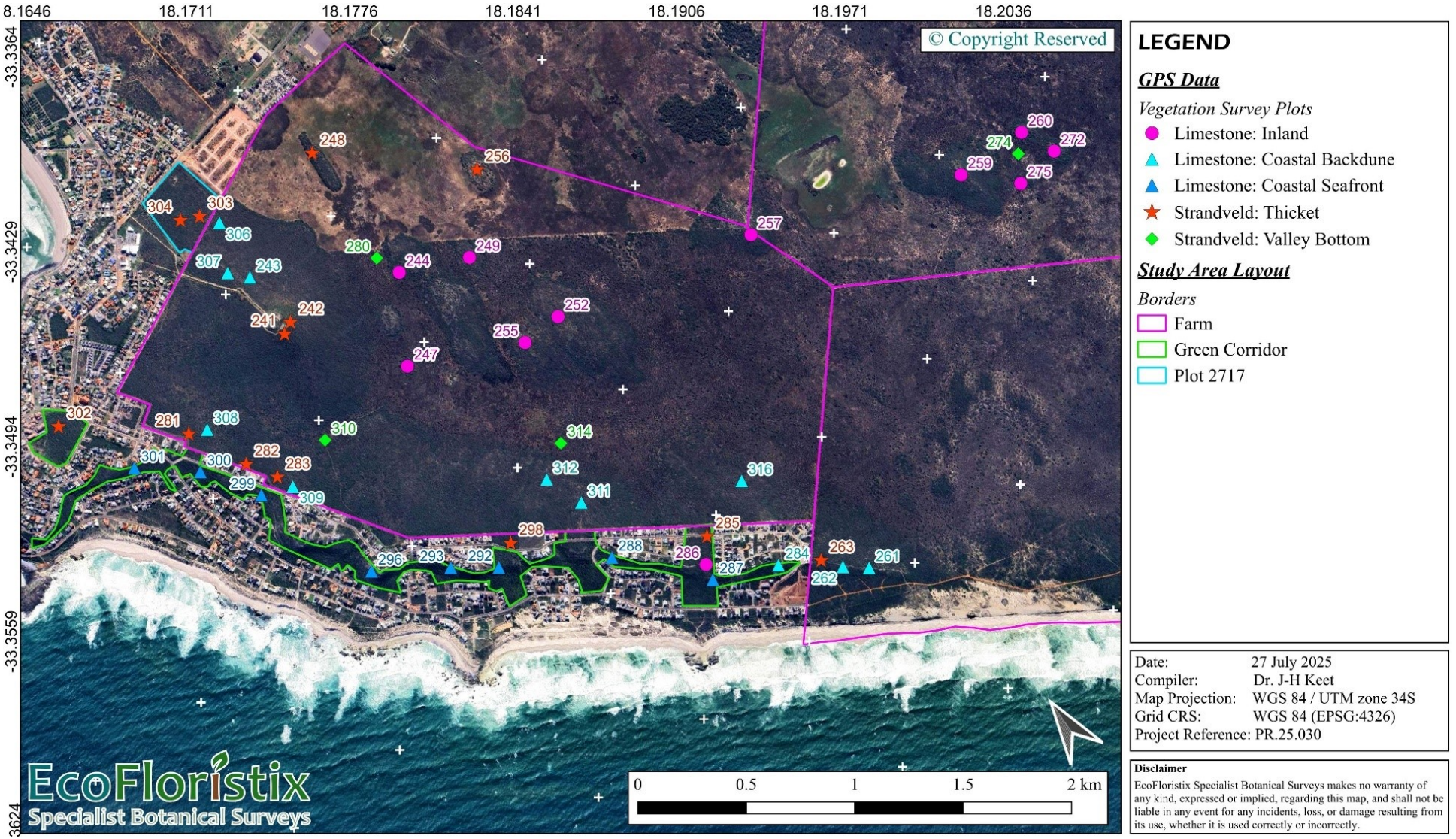

Map 5: Similar to Map 4, but with a closer focus on the core survey area that included limestone vegetation.

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3.3. GIS Modelling and Delineation of Vegetation Type Boundaries

After the main areas of Saldanha Limestone Strandveld were ground-truthed and delineated, a statistical model was run using various GIS layers as inputs (see section 7.3 for methodology) to predict the occurrence of Saldanha Limestone Strandveld elsewhere in the study area. The parameters were fine-tuned such that an acceptable balance could be obtained between the accuracy of predicting true positives (areas of Saldanha Limestone Strandveld) and true negatives (areas that are not Saldanha Limestone Strandveld).

The model demonstrated a high overall balanced accuracy (which accounts for imbalances in the data) of 83.69%. Furthermore, the model exhibited a high specificity (0.9807), meaning it correctly identified a large proportion of negative cases. In contrast, its sensitivity was lower (0.69318), indicating that it missed a notable number of positive cases. The positive predictive value (0.3835) suggests that when the model predicts a positive outcome, it is correct approximately 38.35% of the time, and unfortunately introduces false positives. This means the model predicted areas to be Saldanha Limestone Strandveld that in reality are not. This was deemed acceptable given the threatened status (Critically Endangered) of Saldanha Limestone Strandveld. That is, following a risk-averse and cautionary approach, it was considered a better trade-off to have a model that falsely predicts certain areas as having Saldanha Limestone Strandveld, instead of predicting areas to be absent in Saldanha Limestone Strandveld when in reality it is actually present (false negatives). Moreover, not much can be done to significantly improve the model's performance given that the data will remain inherently imbalanced. This is simply a result of the rarity of Saldanha Limestone Strandveld within the study area, and thus from the start there is not much data regarding this to input into the model.

The result of the predictive model is given by Map 6 to Map 8 where predicted occurrences are indicated in blue pixels. The majority of Saldanha Limestone Strandveld predictions occur on the farm Yzerfontein 560, with a few outcrops occurring on farm Coffee Fontein RE/563, a single and main outcrop on farm Tygerfontein 25/564, and numerous small outcrops within the green corridor. Regarding Tygerfontein 25/564, the model predicted Saldanha Limestone Strandveld to occur in the eastern part of the site, but site inspection revealed that these all consist of dune thickets. Their vegetation patterns superficially resemble, to some extent, those of Saldanha Limestone Strandveld, which is not surprising given that these raised dunes share many common species with the limestone vegetation units (see section 3.2), and thus would exhibit similar values in the respective satellite spectral bands. This same pattern of prediction occurs in the southeast corner of farm Coffee Fontein RE/563, which similarly has such dune thickets that are not truly Saldanha Limestone Strandveld.

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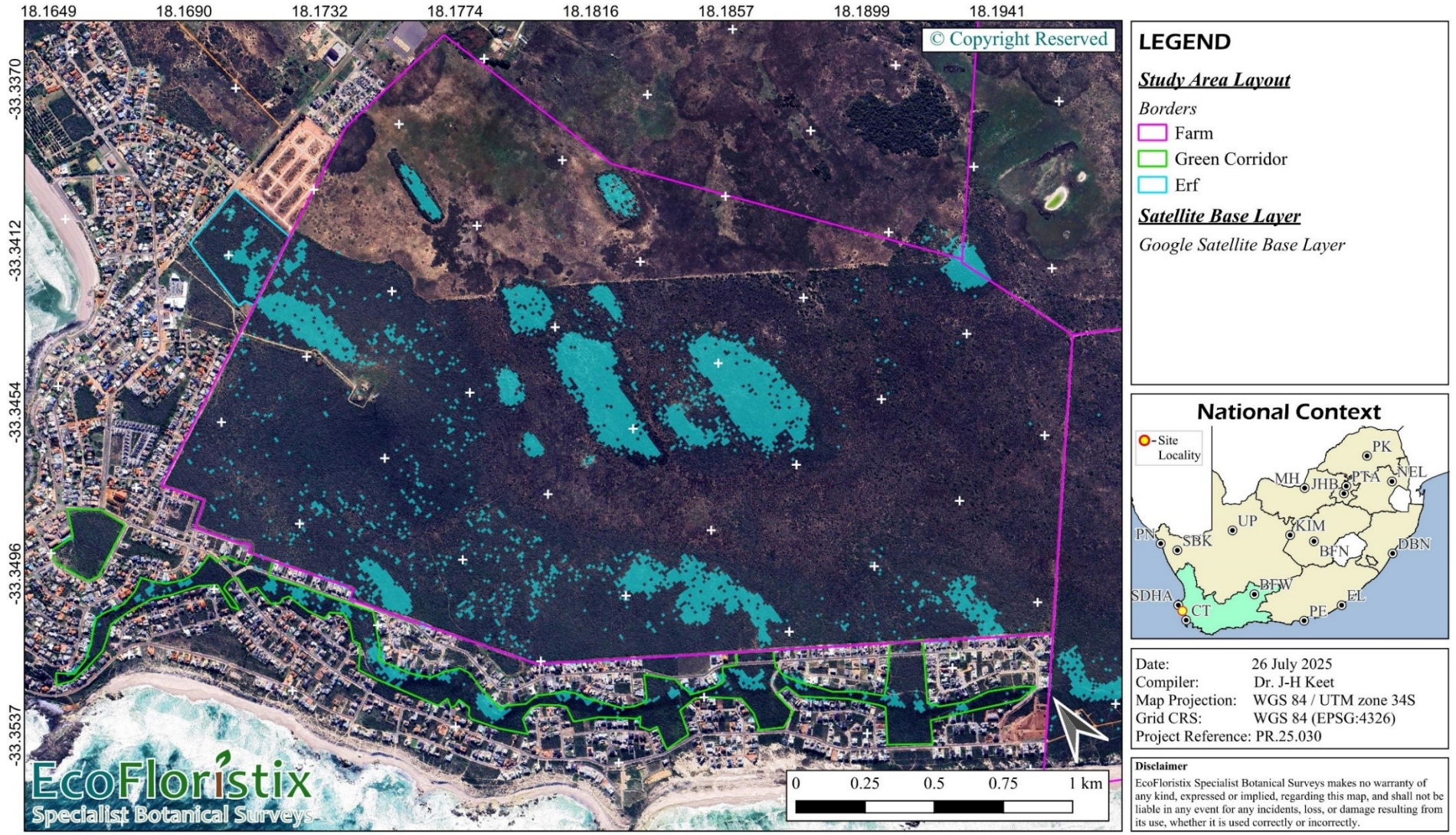

Map 6: Result of the classification model that predicts the presence of Saldanha Limestone Strandveld (indicated by blue pixels) based on ground-truthed data and various GIS layers. Specifically in focus is Yzerfontein 560 (partly), the green corridor, and plot 2717. The resolution of the pixels are 10 x 10 m.

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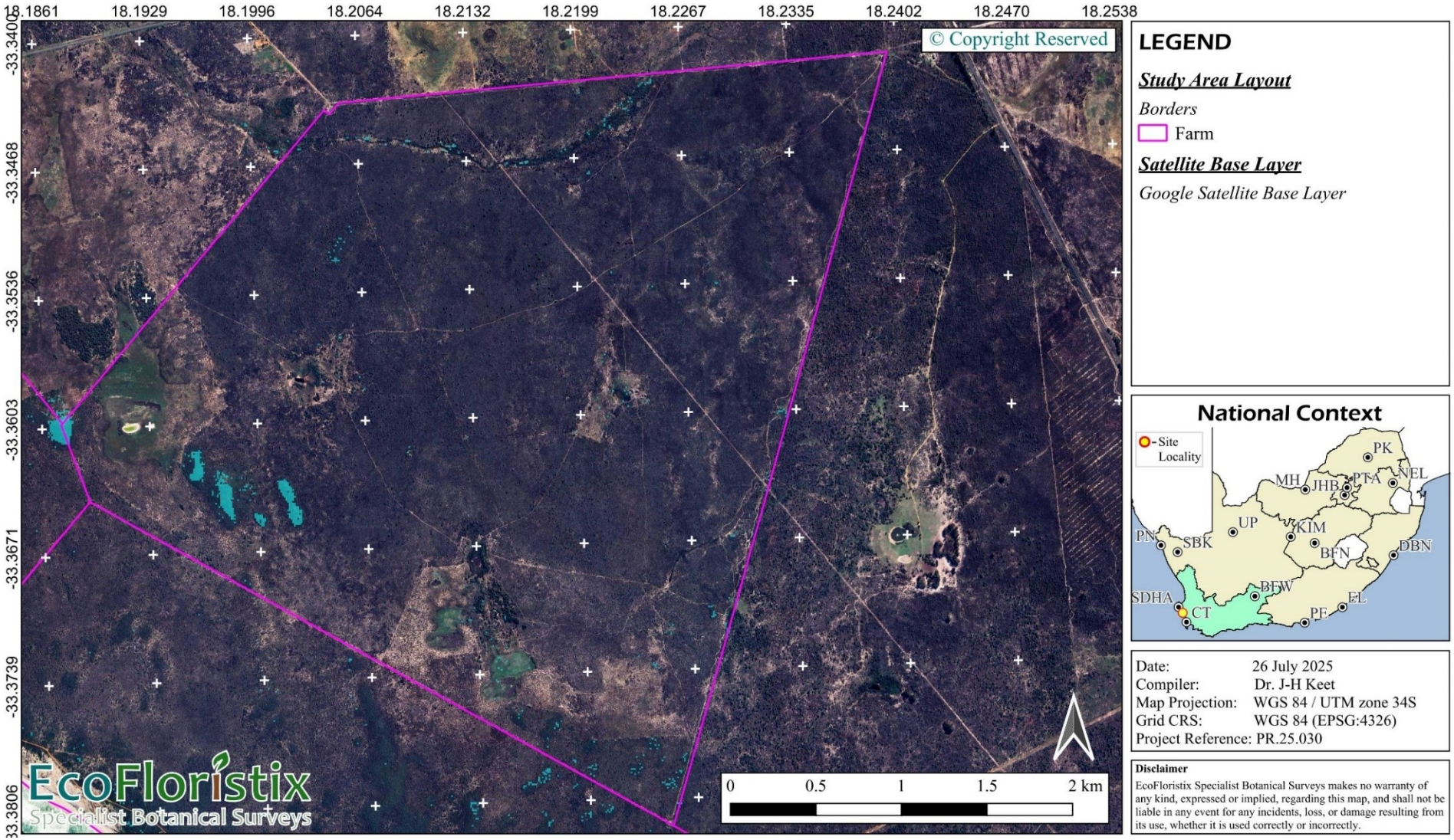

Map 7: Similar to Map 6, but with a specific focus on farm Coffee Fontein RE/563.

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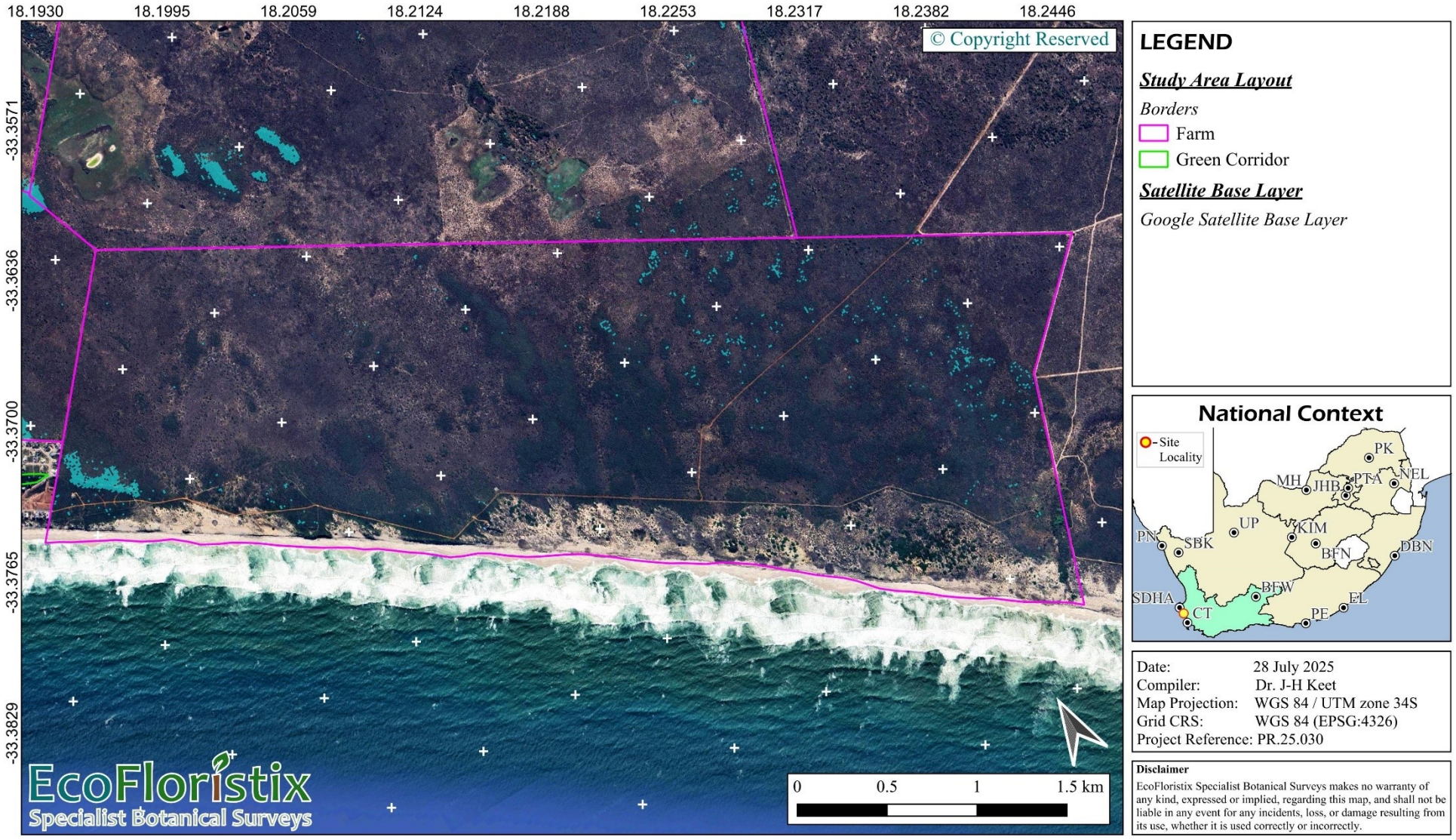

Map 8: Similar to Map 6, but with a specific focus on farm Tygerfontein 25/564.

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3.4. Final Delineation and Mapping of Vegetation Types

All of the data from the site inspection (vegetation plots, hiking, drone reconnaissance trips, vehicle surveys), classification (vegetation data clustering, limestone indicators), and GIS modelling (predictive model and hyper-saturated satellite images) were used to create a final map delineating the various vegetation types found within the study area. However, the focus was specifically on delineating and assessing the condition of Saldanha Limestone Strandveld. Thus, while an attempt was made to classify and delineate as much of the study area as possible, most of the northeastern part of the study area (coinciding with Hopefield Sand Fynbos) was only coarsely mapped.

In the subsequent maps only Saldanha Limestone Strandveld fragments were labelled (to facilitate easy reference). Also, only transition zones for the inland limestone units were mapped. Finally, it must be noted that while much effort was made to accurately map all Saldanha Limestone Strandveld fragments, it is entirely possible that some might have been missed given the difficulties of comprehensively surveying a large area, as well as the difficulties inherent in classifying and delineating plant communities that often grade into and out one of another. It is also equally likely that some over-mapping might have occurred, where some parts of some areas might have been mapped as Saldanha Limestone Strandveld that in reality are not. As already stated, such cases are deemed acceptable given the threatened status (Critically Endangered) of Saldanha Limestone Strandveld and following a risk-averse and cautionary approach.

Note: beach vegetation is not treated further.

3.4.1. Present Ecological State of Saldanha Limestone Strandveld Units

A total of 48 natural Saldanha Limestone Strandveld fragments were delineated (23 coastal seafront limestone, 9 coastal backdune limestone, and 16 inland limestone units), and are indicated by Map 9 to Map 12. These fragments account for about 55.88 ha in total. Approximately 54.11 ha of this is pristine, with only 0.16 ha being slightly degraded (unit number IL08), and 1.16 ha being moderately degraded (units IL02 and IL14). These Saldanha Limestone Strandveld fragments vary considerably in size, the smallest being 314 m^2 (coastal seafront limestone fragment CSL09) and the largest just under 13 ha (inland limestone fragment IL10).

The largest and highest hill (on which the telecommunications tower occurs) cannot really be considered as typical Saldanha Limestone Strandveld since in its great majority it lacks the shallow soils and exposed calcrete rocks characteristic of Saldanha Limestone Strandveld. Moreover, the very top of the hill is of granitic origin and not limestone (see aerial photos D11 and D12 Figure 4 that show differences in vegetation with the surrounding area that is not only attributable to disturbances associated with the tower and its associated activities). This hill also lacks many of the limestone plant species indicators. Only the northern side of it has characteristics that qualify it as more typical of Saldanha Limestone Strandveld (specifically see D11 in Figure 3 which shows this patch; also see fragment CBL05 in Map 9). The rest of it should either be considered of a more transitional nature or be classified as strandveld thicket (as used in the context of this study).

The large ridge that occurs to the eastern side of the urban fringe of Yzerfontein is also not entirely Saldanha Limestone Strandveld, as evidenced by the fact that some of the survey plots (notably 281, 282, and 283) were classified as strandveld thicket (section 3.2) and are thus more similar to all the dune thicket units prevalent on farm Tygerfontein 25/564. The more typical fragments of Saldanha Limestone Strandveld (specifically coastal backdune limestone as used in this report) on this ridge occur on the higher lying areas where soil depth becomes shallower, giving way to the prevalence of calcrete

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rocks and limestone indicator plant species. This can be seen quite clearly when contrasting aerial photo D8 (Figure 4) with photo D4 (Figure 3) showing a very sandy habitat in contrast to an abundance of calcrete rocks. On-site photo S12 (Figure 6) also shows this, where the sandy and thicket nature can be seen.

Regarding the green corridor, Saldanha Limestone Strandveld manifests especially on the edges of the main ridge characterised by altitudinal drops. This is very evident in certain areas where limestone shelves are exposed as entire rock sheets. This can be seen in aerial photo D3 (Figure 3) and on-site photo S8 (Figure 5). Two particularly large coastal seafront limestone vegetation fragments were observed, labelled CSL14 and CSL17 (in fact, photo D3 of Figure 3 views fragment CSL 14, while photo D7 of Figure 4 views fragment CSL17). All of these coastal limestone vegetation fragments have a very high conservation value, since even many of the smaller ones harbour many of the limestone indicator species, which also often occur in high abundances.

The surrounding matrix (i.e., the rest of the green corridor) is characterized by dense thickets that lack these shallow soils and exposed calcrete, and also predominantly lack the characteristic limestone indicator plant species. The Saldanha Limestone Strandveld fragments within the green corridor are largely pristine. In a few instances slight erosion was noted; however, it is not entirely clear whether this can be regarded as true manmade disturbances instead of natural occurrences, given the preponderance of limestone to erode easily.

Finally, regarding the inland limestone fragments of Saldanha Limestone Strandveld, these present as very unique habitats given that they are essentially "islands" within a matrix of lowland vegetation of a completely different composition and structure. This is especially evident in the cluster dendrogram (Figure 2 in section 3.2) that shows a major division between the two restio-dominated sandy units (valley bottom strandveld essentially corresponding to Saldanha Flats Strandveld, and sand fynbos essentially corresponding to Hopefield Sand Fynbos) and the limestone units. Moreover, numerous limestone indicator species were found in most of them, which furthermore testifies to their unique nature within the landscape. Thus, given the distinct separation, in terms of species composition, between these limestone "island" outcrops and the surrounding restio dominated matrix, these inland outcrops and the surrounding lowland areas present a large variety in microhabitats and species turnover, and have a high conservation value. The closest fragment (IL08) of all the inland limestone fragments occurs 1.4 km from the shoreline.

Some of these, especially fragments IL15 – IL18 on farm Coffee Fontein RE/563, are noteworthy because they occur a minimum of 2.4 km from the seashore, yet even harbour plant species that characteristically occur very close to the shoreline (such as *Phylica ericoides* var. *ericoides*). It is also amazing that the second smallest of all the inland limestone fragments — IL17 (see photo S5 in Figure 5) — which is just shy of 4500 m^2 and which occurs 2.4 km from the seashore, even harbours numerous individuals of the Saldanha Limestone Strandveld endemic *Muraltia harveyana* (a Vulnerable species). This again serves to reiterate the high conservation value of these inland limestone outcrops, together with their transition zones and surrounding matrix.

3.4.2. Miscellaneous Observations

As mentioned, a small part of granite vegetation (likely conforming to Saldanha Granite Strandveld) was observed as occurring on the largest hill in the area (on which the telecommunications tower occurs). While not extensively surveyed

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given that it is not limestone and did not form a core part of this study, it might harbour some interesting species and would be worthy of a spring season survey.

A large part of farm Yzerfontein 560 is highly disturbed and consists of previously ploughed lands. Extensive stands of the native sand loving grass *Ehrharta villosa* var. *villosa*, as well as large concentric patches of *Carpobrotus edulis* (clearly seen on satellite images) are regular occurrences. Two large and dense invasive alien *Acacia* stands also occur on farm Yzerfontein 560.

Regarding farm Coffee Fontein RE/563, quite a few plant Species of Conservation Concern were observed, some of which were very abundant. This is especially true of *Leucospermum tomentosum* (Near Threatened) and *Aspalathus ternata* (Near Threatened). A highlight was the observation of two Critically Endangered species, namely *Amphithalea ericifolia* subsp. *erecta* and *Erica bolusiae* var. *bolusiae*. The latter was quite abundant in a small wetland area occurring to the extreme northeast of the farm, while a single individual of the former was observed close to this wetland. A small stream also traverses the northern part of the farm with characteristic riparian vegetation bordering it.

Finally, apart from the two dense *Acacia* stands observed on farm Yzerfontein 560, very few invasive alien plant species were observed throughout the study area. In contrast, the farm bordering the east of Coffee Fontein RE/563, namely Groot Water 569, has extensive stands of *Acacia saligna* (Port Jackson wattle).

3.4.3. Vegetation Types of the Study Area as per VegMap

Map 13 showcases the vegetation types defined in the context of this report as they equate to units circumscribed by VegMap. Classifying vegetation on-site into the categories defined by VegMap presents several challenges, primarily because the map's classifications are broad, often regional, and based on dominant species and ecological processes. A key difficulty is that local variations in soil type/depth, topography, and/or disturbance history can lead to large differences in species composition and community structure within a single mapped vegetation type. A prime example here constitutes the ploughed fields that would've been Saldanha Flats Strandveld, but due to their disturbance history now harbour a completely different suite of dominant plant species. Similarly, the two dense invasive *Acacia* stands (falling just outside the study area border) also would've been Saldanha Flats Strandveld, but is now dominated by species that are not characteristic of the vegetation type, and also differs markedly from the mentioned ploughed fields (and even the pristine areas dominated by sonkwasriet).

Furthermore, as mentioned in section 2.2, transitional zones between different vegetation types often create a mosaic of species from both categories, making it difficult to assign a definitive classification. The National Vegetation Map is a powerful tool for large-scale planning and conservation, but its generalized nature means that it cannot fully capture the fine-scale complexity and dynamic nature of real-world ecosystems. This is exactly why site-specific classifications of plant communities are preferred above VegMap vegetation types.

Nevertheless, given that redlist statuses and other relevant information are tied to vegetation types as defined by VegMap, all of the plant community types on site were classified into vegetation types as best possible. However, it must be stressed that these classifications should not be interpreted alone, and should be studied carefully together with the preferred classifications given by section 3.2 and Map 9 – Map 12.

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Although Saldanha Flats Strandveld has been chosen to represent the valley bottom strandveld as used in this report, it does not conform well to VegMap definitions (especially near the coast) and should likely be considered a vegetation type in its own right. However, given that limited surveying occurred in it, since it was not a major focus, it has been kept as Saldanha Flats Strandveld, which is based primarily on its topographic nature. Thus, it must be noted that the intention with this classification is not that it should be interpreted as being typical Saldanha Flats Strandveld.

Similarly, the transitional zones surrounding the small inland limestone outcrops ("islands") have been classified as Langebaan Dune Strandveld. They do not have a characteristic open vegetation structure, abundance of calcrete rocks and shallow soils, or limestone indicator species, and thus do not conform well to typical Saldanha Limestone Strandveld. However, they also differed markedly form the surrounding lowland vegetation matrix that is dominated by *Willdenowia incurvata*, which has been classified as Saldanha Flats Strandveld. Thus, the only option left is Langebaan Dune Strandveld.

Finally, the highly modified ploughed fields and invasive *Acacia* stands have been classified as Saldanha Flats Strandveld purely because it would've been present prior to these disturbances. They do not truly conform to Saldanha Flats Strandveld.

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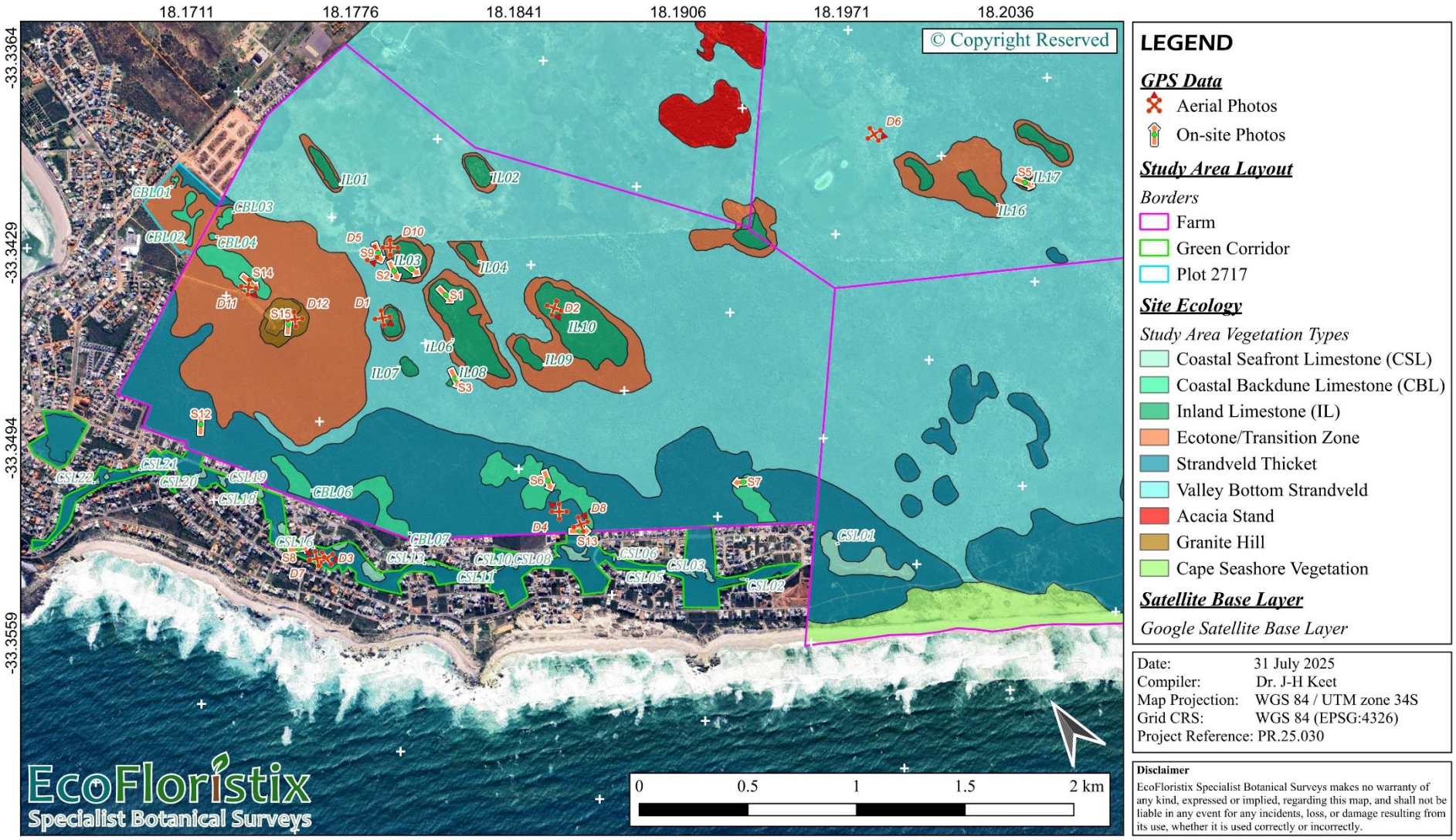

Map 9: Final delineation of Saldanha Limestone Strandveld and other relevant vegetation types within the study area. This map specifically focuses on farm Yzerfontein 560 and the green corridor.

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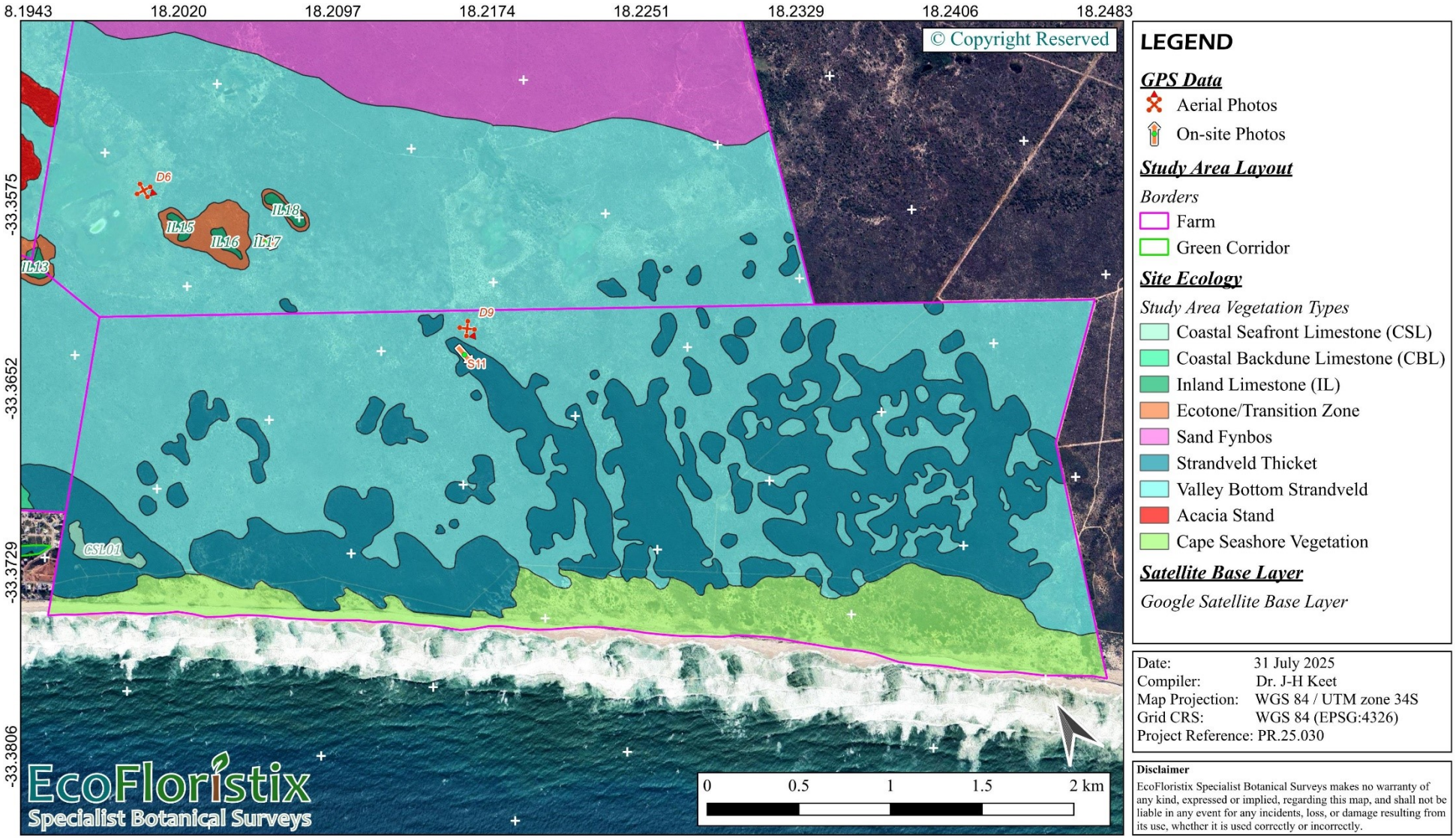

Map 10: Similar to Map 9, but with a focus on farm Tygerfontein 25/564.

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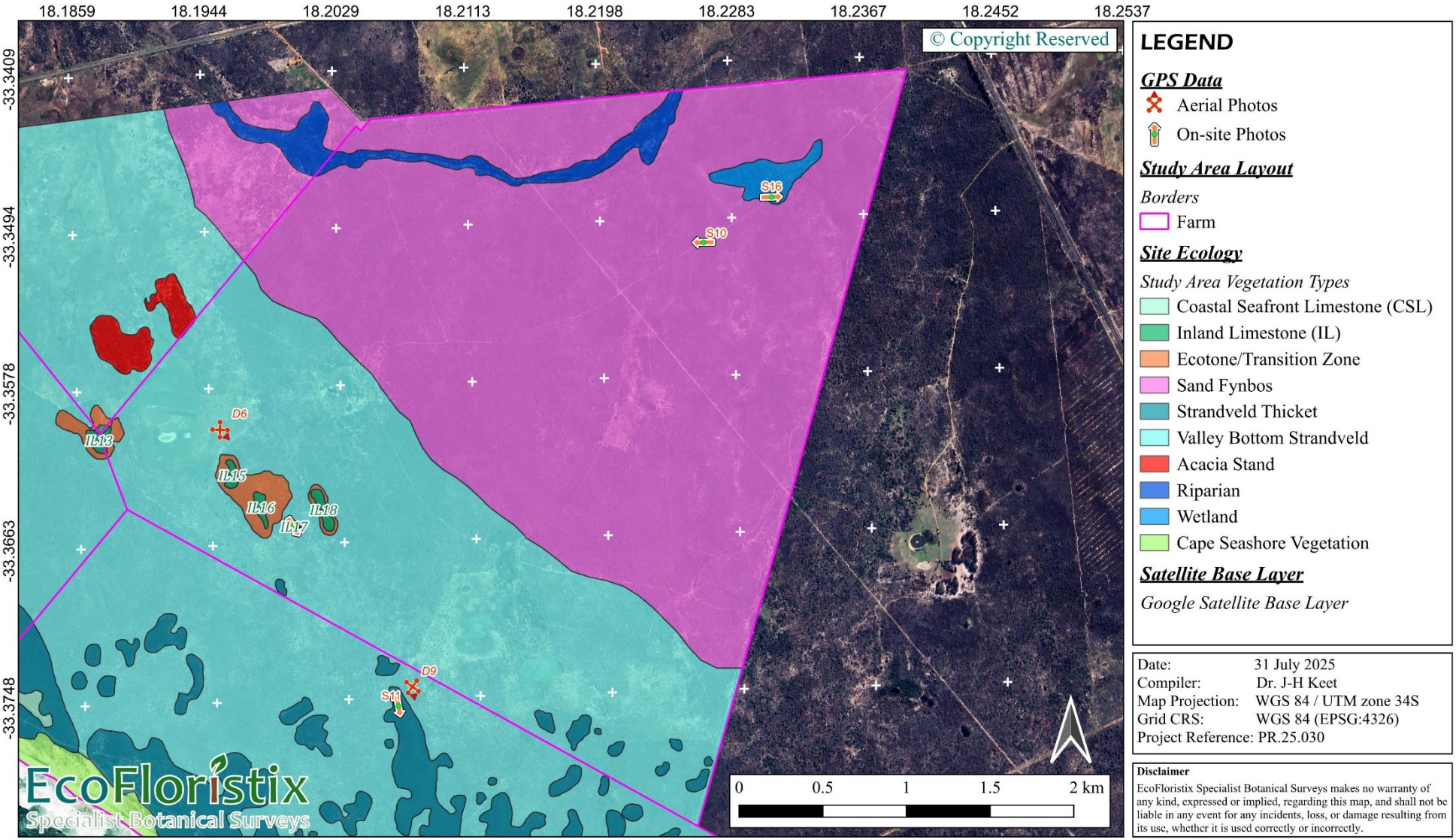

Map 11: Similar to Map 9, but with a focus on farm Coffee Fontein RE/563.

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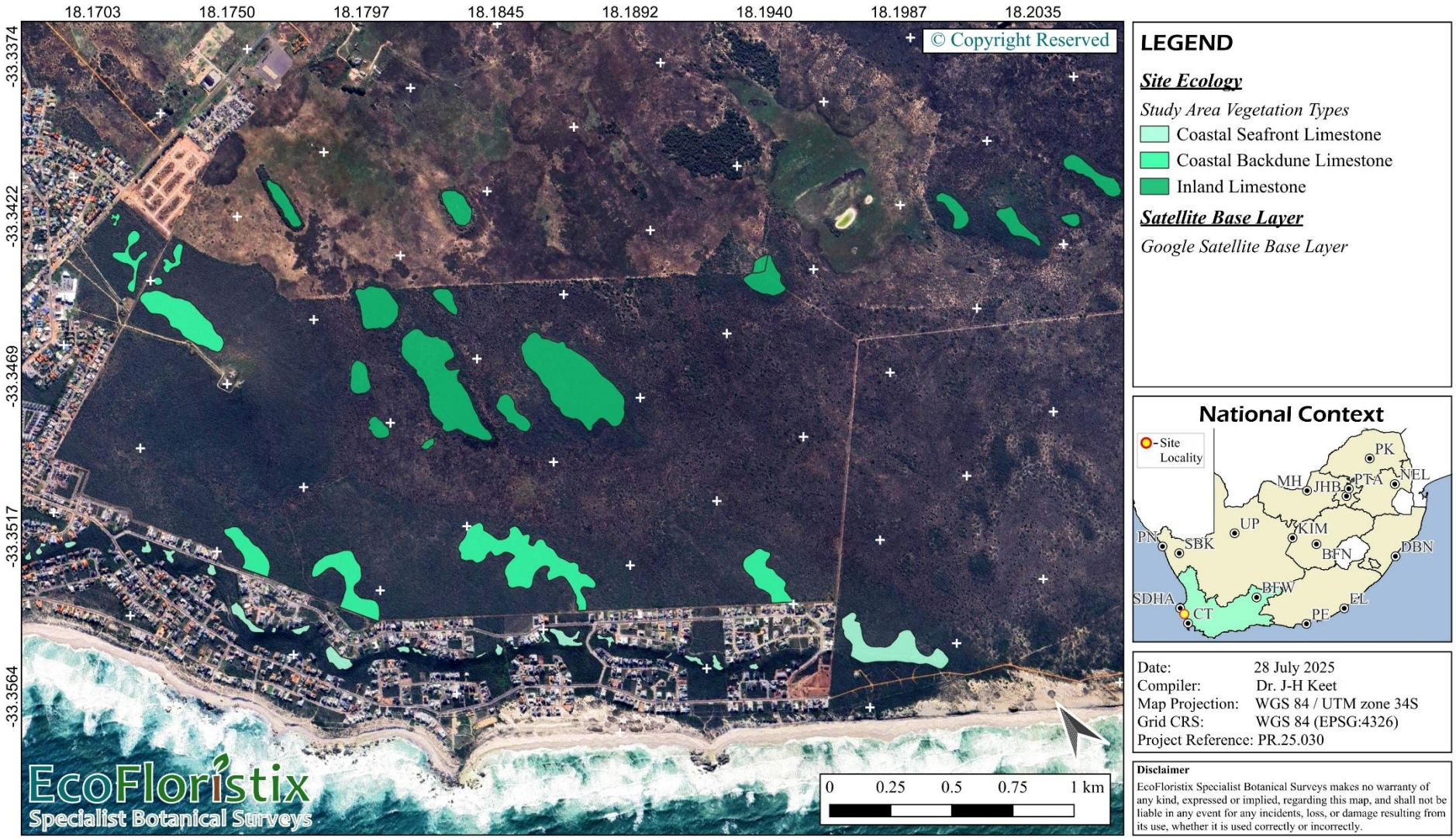

Map 12: Similar to Map 9, but this map specifically showcases only the presence of the various Saldanha Limestone Strandveld fragments, delineated as inland limestone, coastal backdune limestone, and coastal seafront limestone.

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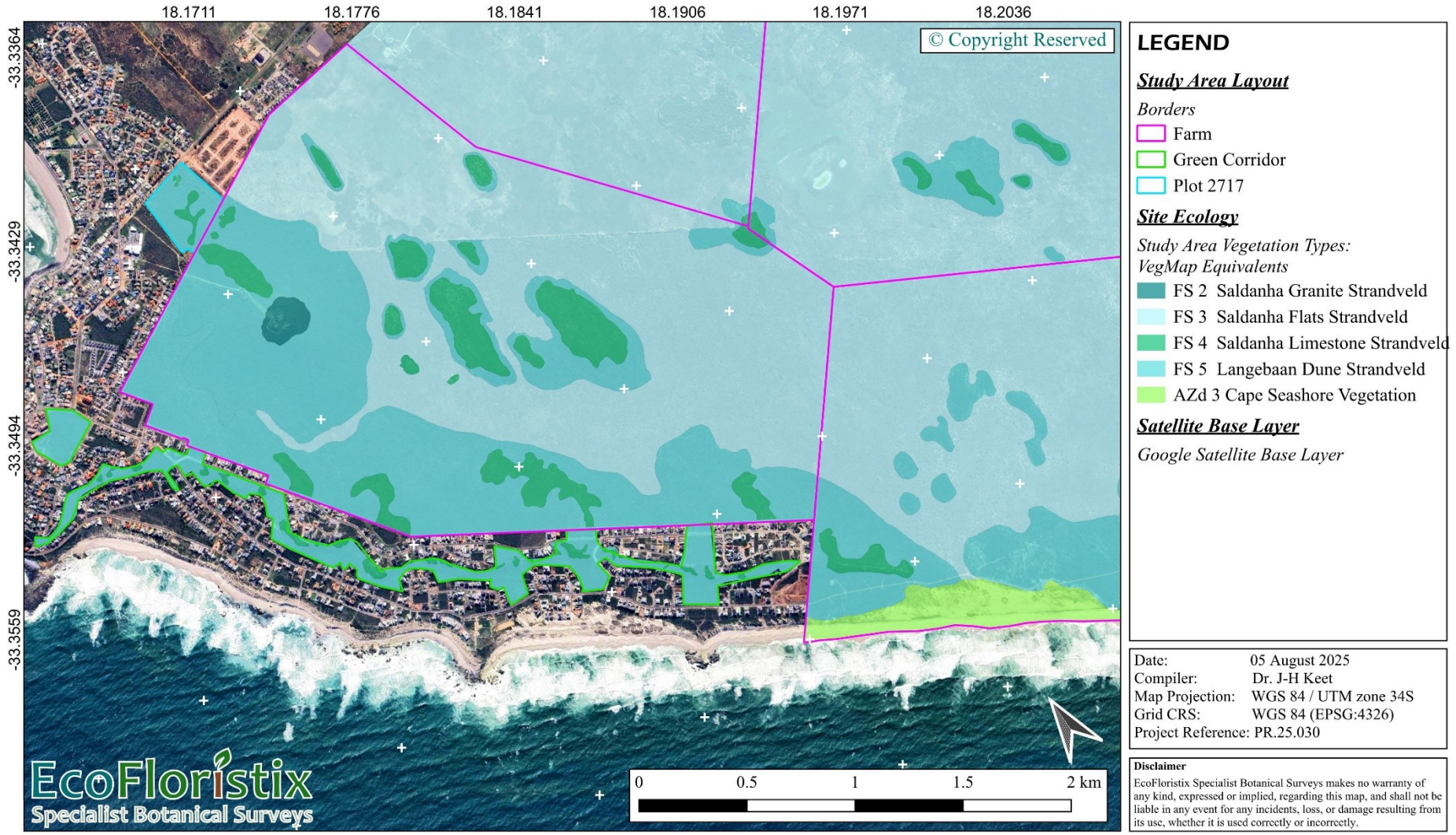

Map 13: Study area vegetation types as they equate to units circumscribed by VegMap. Note that some of the vegetation on site does not conform well to VegMap definitions. See section 3.4.3 for details.

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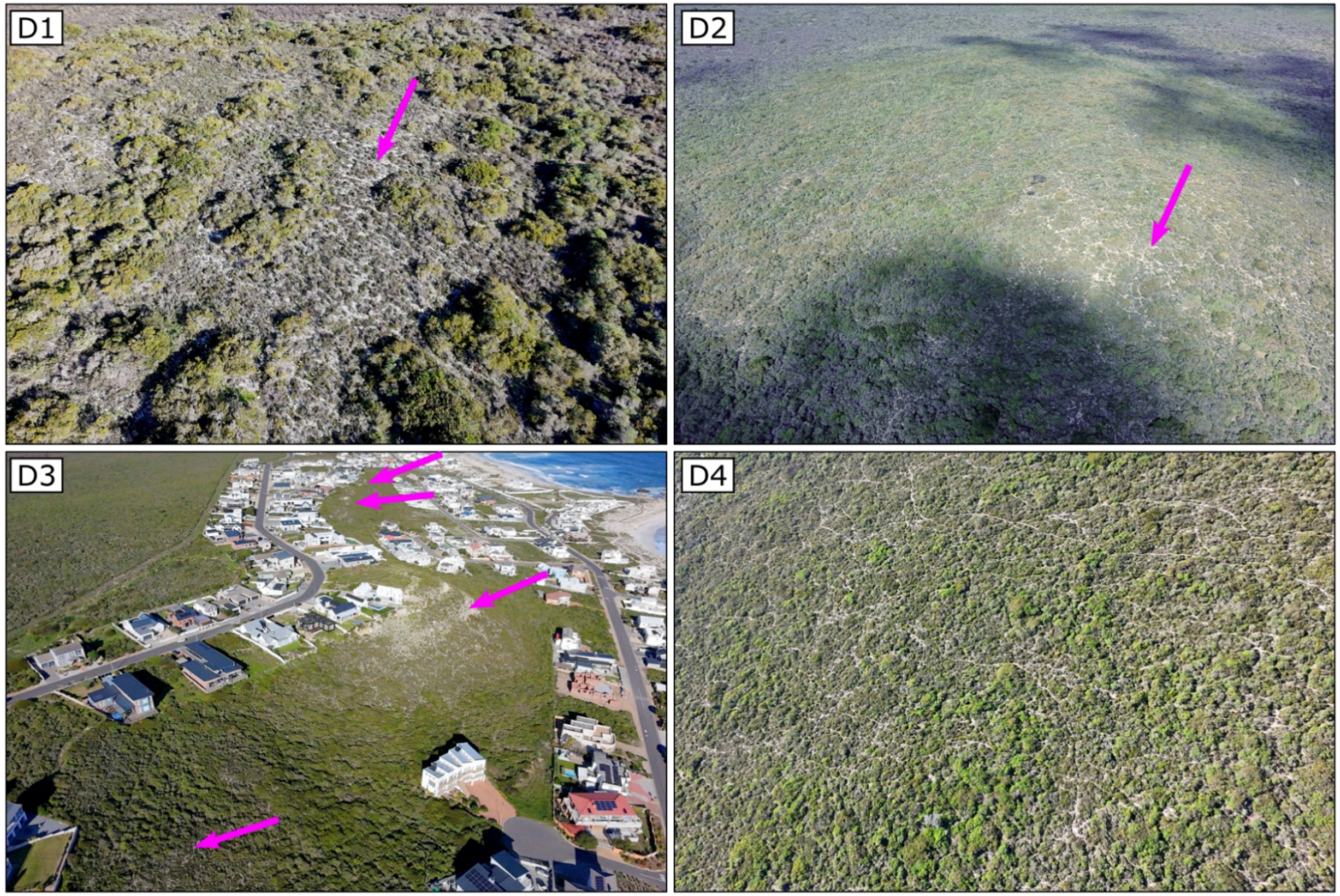

Figure 3: Aerial photos of Saldanha Limestone Strandveld (indicated with arrows for clarity where relevant). D1 and D2 of inland limestone fragments showing the characteristic open nature of Saldanha Limestone Strandveld. D3) Coastal seafront limestone, with a particularly large fragment (CSL14) in the centre. D4) Example of coastal backdune limestone indicating numerous open patches within a matrix of dune thicket. See map Map 9 – Map 11 for photo localities (indicated as Aerial Photos); the same for all the aerial and on-site photos that follow.

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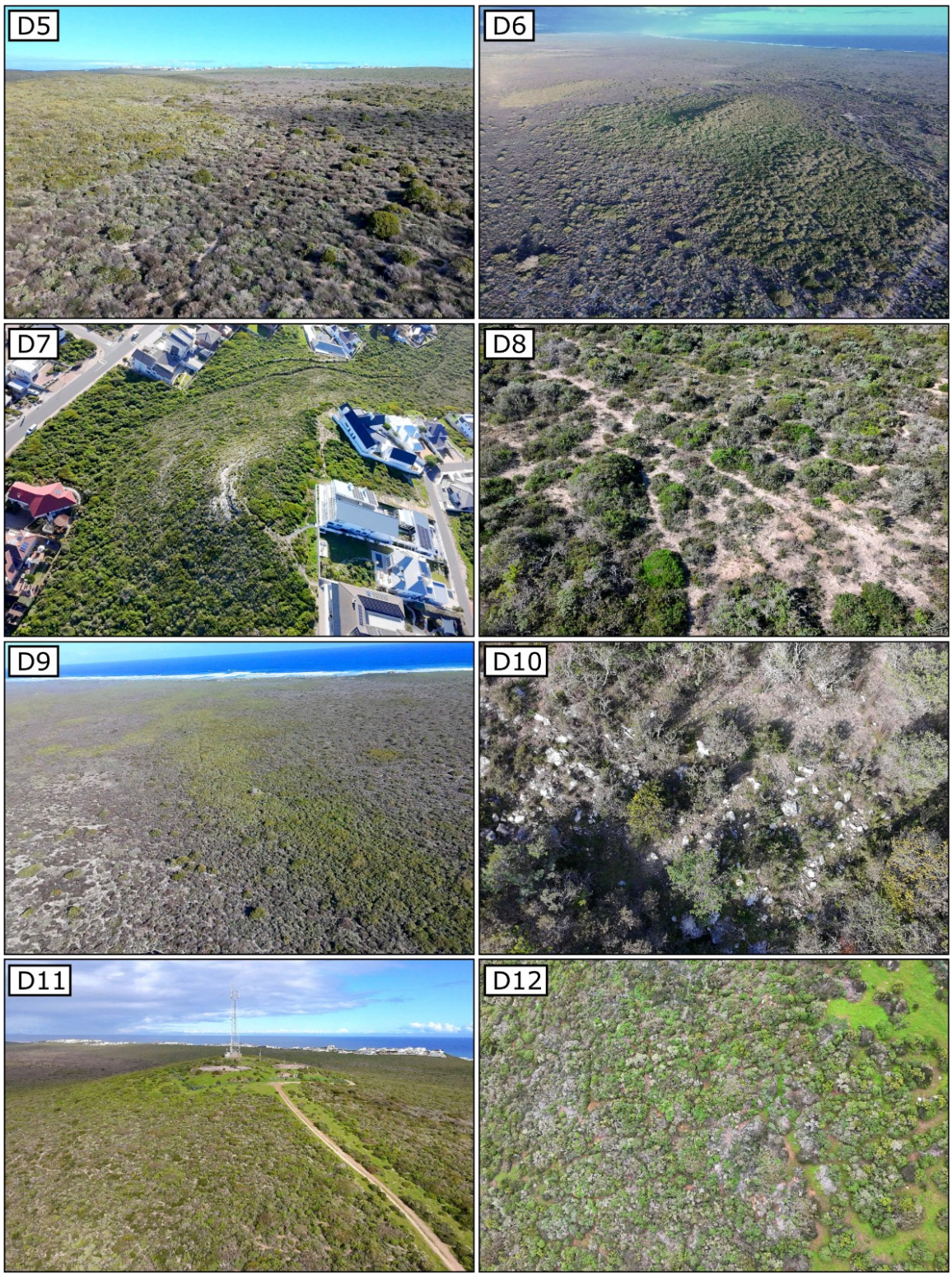

Figure 4: Additional Aerial photos of Saldanha Limestone Strandveld fragments, as well as other habitats. D5 and D6 are of inland limestone fragments, with D6 representing units (IL15 – IL18) that are the furthest from the seashore. D7) Another particularly large fragment of coastal seafront limestone (fragment CSL17). D8) Open sandy area of strandveld thicket that transitions into one of the coastal backdune limestone fragments (CBL08). D9) View of strandveld thicket occurring on sand dunes (light green areas) within a matrix of valley bottom strandveld (dark grey areas dominated by *Willdenowia incurvata*). D10) Direct overhead photo of calcrete rocks in the inland limestone fragment IL03. D11 and D12 of the granite vegetation on top of the highest hill showing an abundance of grass cover as well as darker soils.

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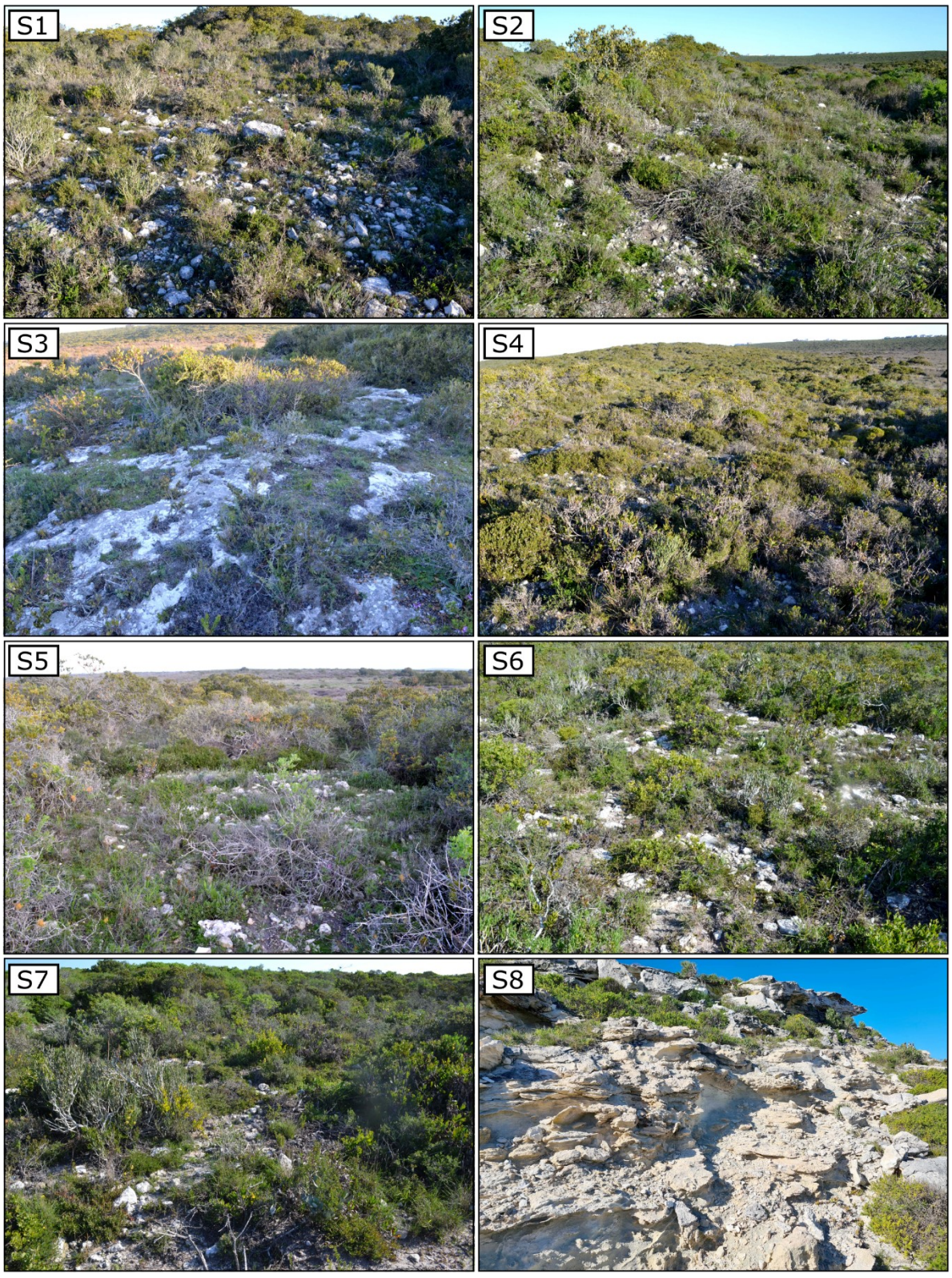

Figure 5: On-site photos of the various Saldanha Limestone Strandveld units. S1 – S5 all represent inland limestone fragments showing an open vegetation structure (as opposed to the dense thickets surrounding it) with numerous calcrete rocks. S6 and S7 represent coastal backdune limestone, also showing a more open structure but with more dune elements also present. S8 represents a large exposed limestone shelf in fragment CSL17 (coastal seafront limestone).

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Figure 6: Additional on-site photos of other habitats. S9) Valley bottom strandveld dominated by *Willdenowia incurvata*. S10) Sand fynbos dominated by *Thamnochortus punctatus* and *Leucospermum tomentosum*. S11) Strandveld thicket showing the particularly dense nature of the vegetation. S12 and S13 of strandveld thicket on the ridge east of the urban fringe showing the sandy nature of the vegetation type and an absence of calcrete rocks. S14) View towards the main hill showing a dense vegetation patch; this was particularly difficult to classify given the atypical nature of Saldanha Limestone Strandveld, but the surrounding area was more open with a few indicator species and the area was classified following a risk-averse and cautious approach. S15) View of granite rocks on top of the main hill showing their darker colour, as well as the coarser nature of the soil. S16) Wetland area in the northeastern part of farm Coffee Fontein RE/563 (the pink shrub is *Erica bolusiae* var. *bolusiae*, with *Restio quinquefarius* surrounding it).

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3.5. Assessment of Conservation Value

The comprehensive assessment of conservation value (or ecological importance/sensitivity) can pose a significant challenge, particularly when considering SCC and threatened vegetation types. The inherent difficulty stems from the multi-dimensional nature of "value", encompassing ecological functionality, distinctiveness/uniqueness, cultural significance, and even the provision of ecosystem services. Quantifying these diverse facets is frequently hampered by data deficiencies, especially concerning the population dynamics, distributional ranges, and specific habitat requirements of many rare or elusive species. Furthermore, the complex interdependencies between species often result in unforeseen ecological cascades, making the prediction of long-term conservation outcomes difficult. The evaluation of conservation value is further complicated in transition zones, or ecotones. These areas, characterized by their inherent dynamic nature, serve as critical ecological interfaces. The simultaneous presence of diverse species from adjacent ecosystems, even though they might be common within the broader landscape, exacerbates the challenge of prioritizing conservation efforts for such areas.

Given this, the conservation value of the various vegetation units has been assessed as follows (see Map 14 – Map 16):

- All pristine units of Saldanha Limestone Strandveld are considered to be Very High in their conservation value. This is firstly due to the vegetation type itself being listed as Critically Endangered, as well as the fact that the units harbour a diversity of SCC. Those units that are subject to degradation were considered to be either High or Medium depending on the extent of degradation present. They still represent valuable areas that might be rehabilitated and added to conservation targets.
- Langebaan Dune Strandveld has been assessed as having a Medium conservation value. Although the vegetation type is listed as Endangered, not many SCC were found to occur in, and it is quite abundant within the southern part of the study area.
- Saldanha Flats Strandveld was assessed as having a Medium conservation value. Firstly, similar to Langebaan Dune Strandveld, it is quite abundant within the southern part of the study area and did not have many SCC. Furthermore, much of this unit is dominated by the common sonkwasriet (*Willdenowia incurvata*), and should likely be considered a vegetation type in its own right, and not necessarily Saldanha Flats Strandveld *per se*. Thus, it is not considered as conservation worthy in this context as the Saldanha Limestone Strandveld units. Nevertheless, for the exact reason given, i.e. that it might be a vegetation type in its own right (which could become known with more study), it must not be considered any lower than Medium. Its pristine nature, especially in the southern part of the study area, further warrants this. In fact, together with the transitional zones and inland limestone vegetation fragments, it might even be considered as bordering on High conservation value.
- Hopefield Sand Fynbos was assessed as having a High conservation value. Although this vegetation type is listed as Least Concern, two Critically Endangered plant species were found in it. Moreover, other SCC were also found in it, some of which have a high abundance, especially *Leucospermum tomentosum*. Thus, it serves as a very valuable area for conserving large populations of SCC.
- Saldanha Granite Strandveld was assessed as having a High conservation value mostly because it is listed as a Critically Endangered vegetation type, and because it is a unique feature within the broader landscape. Unfortunately, given time constraints it was not surveyed extensively.

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- Transition zones were assessed as having a High conservation value. Although their dynamic nature complicates their classification, they serve as important ecological interfaces and often harbour species characteristic of their neighbouring vegetation types. In that sense they can act as reservoirs for these species, especially if they are SCC (or limestone indicators in this context), thereby contributing to the gene pool and acting as buffers against disturbances.
- The wetland area within farm Coffee Fontein RE/563 was assessed as having a High conservation value given that it harbours a large population of the Critically Endangered *Erica bolusiae var. bolusiae* and because its functional importance within the landscape (as is true of all wetlands).
- The stream that traverses farm Coffee Fontein RE/563 was assessed as having a Medium conservation value given that it is invaded to some extent by *Acacia saligna*.
- Finally, the highly degraded ploughed lands were assessed as having a Low conservation value, while the two densely infested invasive *Acacia* stands were assessed as having a Very Low conservation value.

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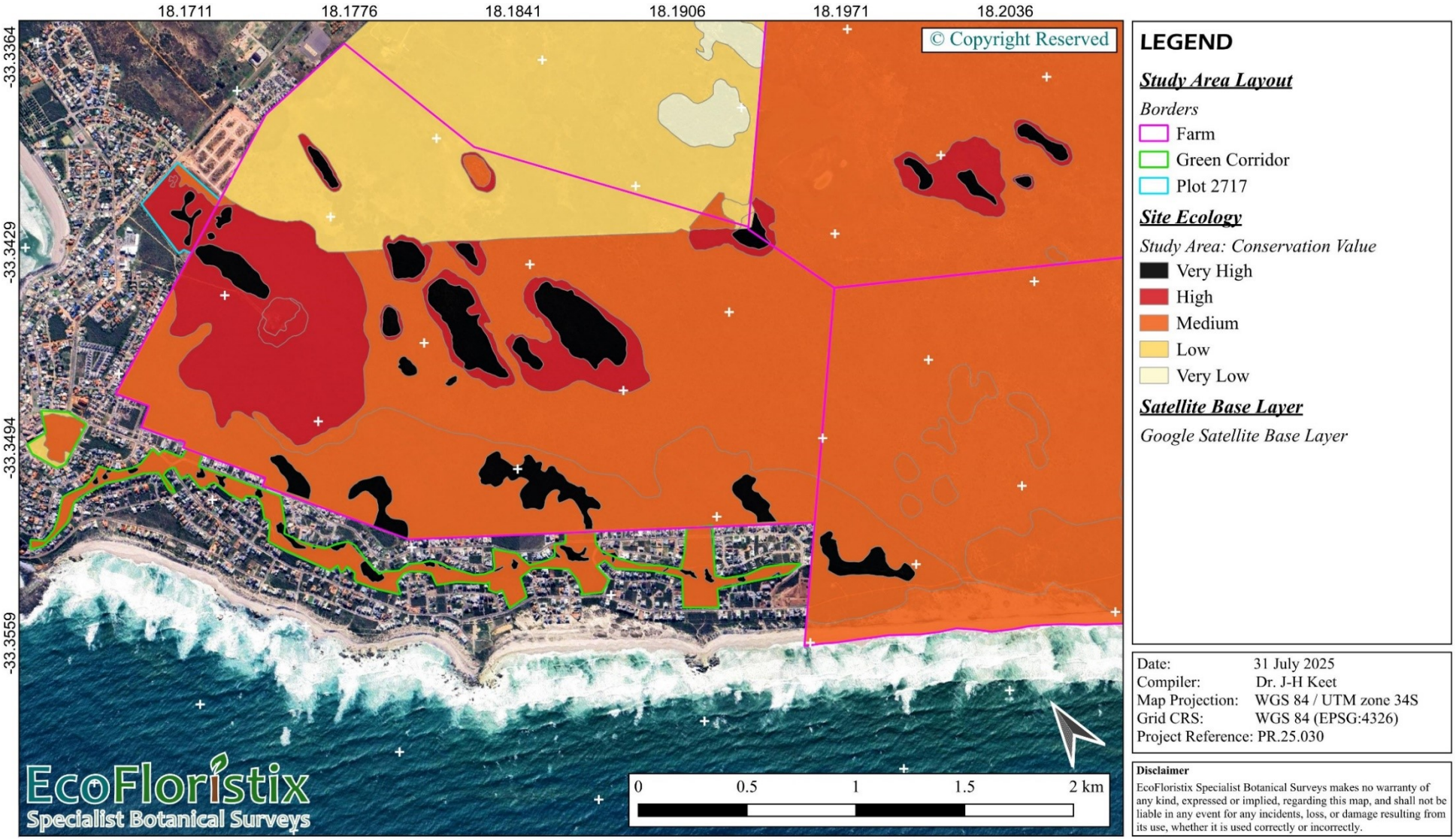

Map 14: Conservation value assessment of the study area. This map specifically focuses on farm Yzerfontein 560, plot 2717, and the green corridor.

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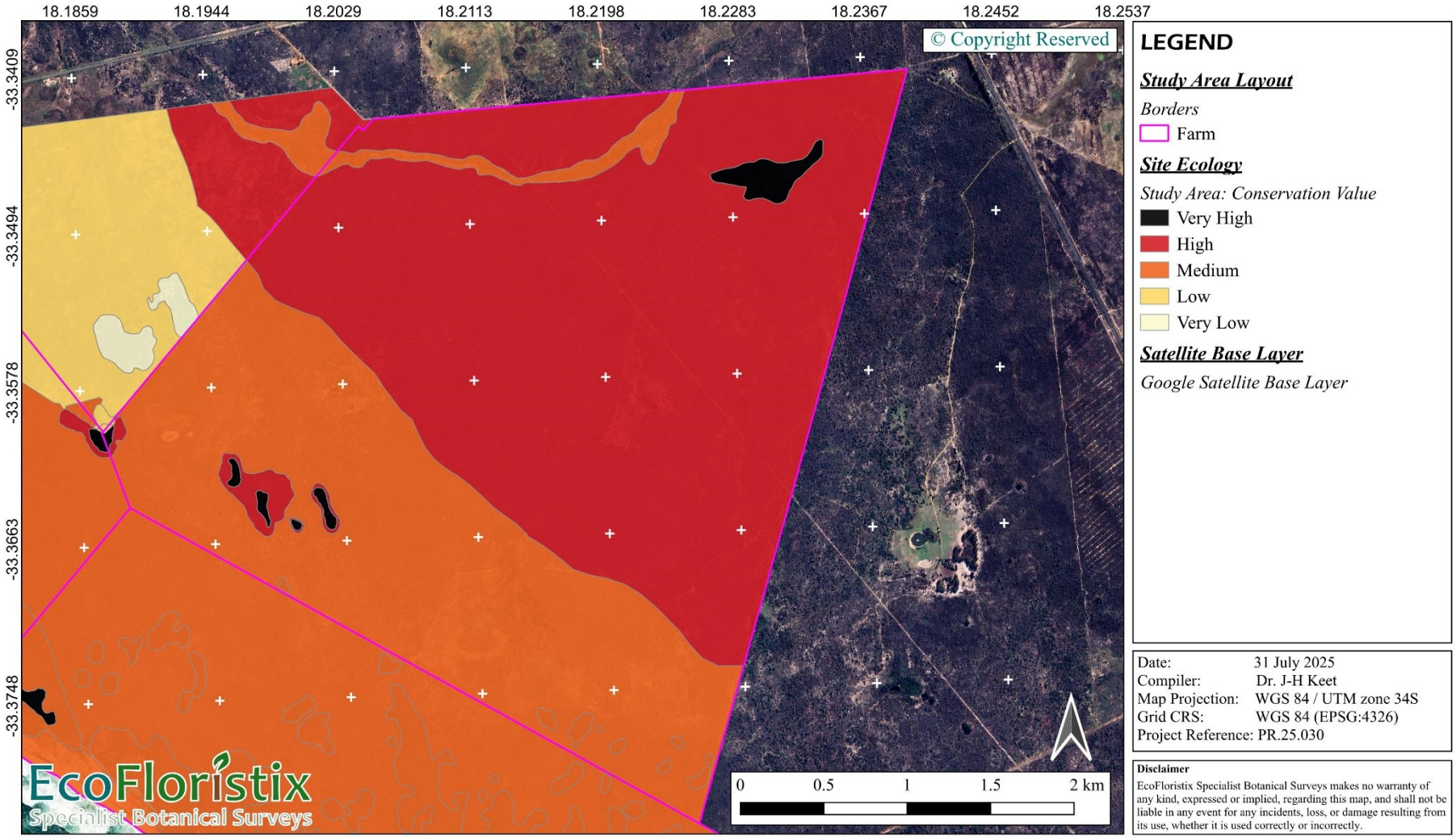

Map 15: Similar to Map 14, but with a specific focus on farm Coffee Fontein RE/563.

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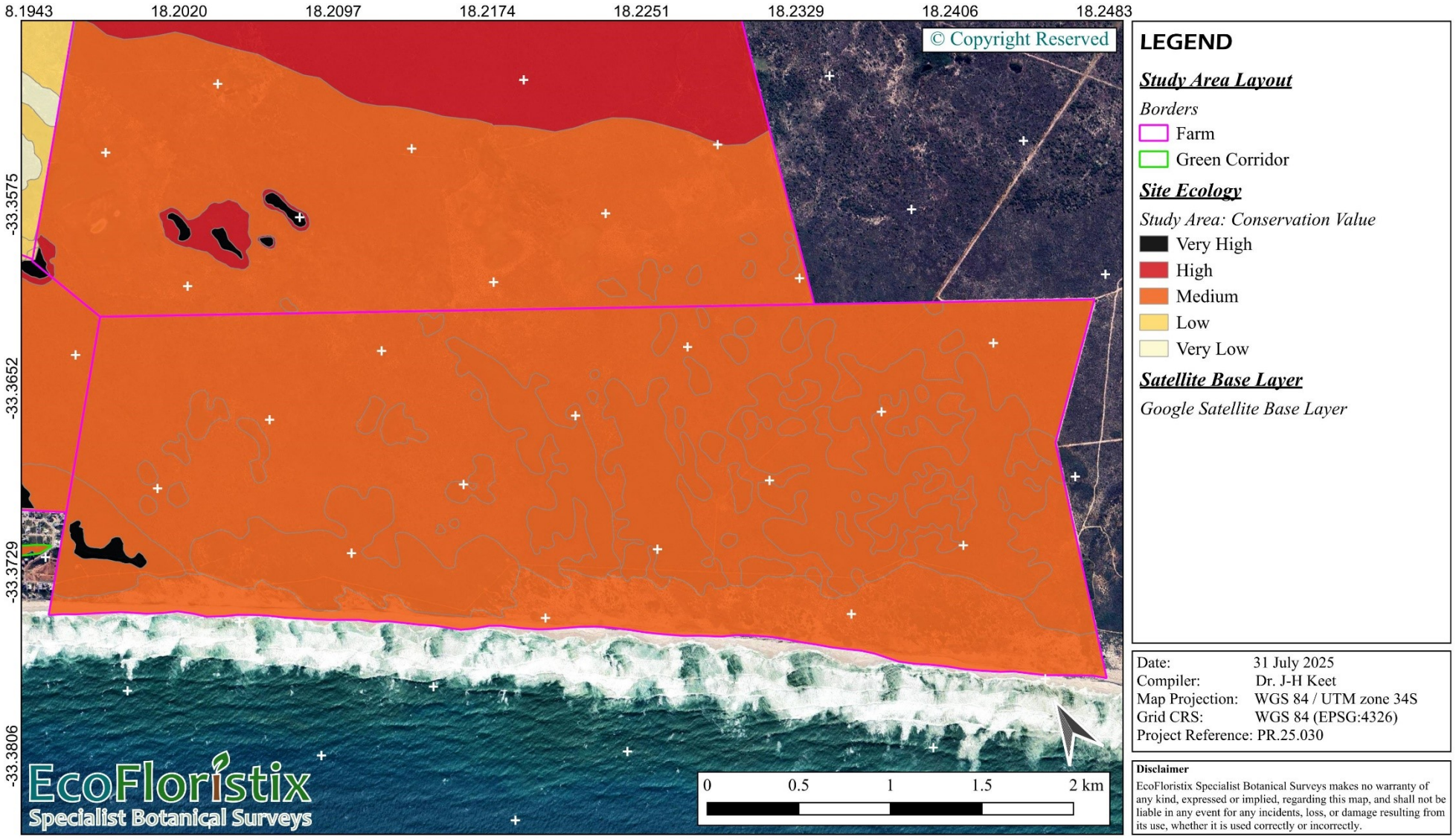

Map 16: Similar to Map 14, but with a specific focus on farm Tygerfontein 25/564.

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4. Conclusion

The extensive vegetation survey conducted across the study area has successfully delineated and assessed the condition of various vegetation types, with a particular emphasis on the Critically Endangered Saldanha Limestone Strandveld. The multifaceted approach, integrating ground-truthing, drone reconnaissance, detailed botanical surveys, cluster analysis, and GIS predictive modelling, has provided a robust understanding of the area's ecological landscape.

A total of 48 distinct Saldanha Limestone Strandveld fragments were identified, collectively covering approximately 55.88 hectares. It is highly encouraging that 54.11 hectares of this critically important vegetation type remain pristine, underscoring the success of conservation efforts in these areas. The presence of 19 Species of Conservation Concern (SCCs), including two Critically Endangered species (*Amphithalea ericifolia* subsp. *erecta* and *Erica bolusiae* var. *bolusiae*), highlights the significant biodiversity value of the study area, particularly within Saldanha Limestone Strandveld and Hopefield Sand Fynbos communities.

The inland limestone "islands" of Saldanha Limestone Strandveld are particularly noteworthy for their unique species composition and high conservation value, existing as distinct ecological enclaves within a differing surrounding matrix valley bottom strandveld (Saldanha Flats Strandveld). Similarly, the coastal seafront limestone fragments, despite their often-smaller size, are vital habitats harbouring numerous limestone indicator species, some of which are also SCC.

While the predictive model for Saldanha Limestone Strandveld demonstrated strong accuracy and a cautious approach to avoid false negatives, it is important to acknowledge the inherent challenges in delineating dynamic vegetation boundaries and the potential for minor misclassifications.

This assessment assigns Very High conservation value to all pristine Saldanha Limestone Strandveld units, reflecting their Critically Endangered status and high SCC diversity. Degraded units still hold High or Medium value, indicating their potential for rehabilitation. Hopefield Sand Fynbos also received a High conservation value due to its significant SCC populations, including two Critically Endangered species. Saldanha Granite Strandveld similarly holds High value as a Critically Endangered and unique landscape feature. Finally, transition zones have a High value due to their role as important ecological interfaces and reservoirs for species, including SCCs.

Continued monitoring and refinement of mapping efforts will be crucial, and a spring survey will be highly advantageous to supplement current knowledge of the study area. Furthermore, the observed disturbances, such as previously ploughed lands and invasive alien plant species, particularly on farm Yzerfontein 560, would benefit from targeted management interventions to preserve the ecological integrity of the broader landscape.

Ultimately, this report provides a useful assessment to be used in ongoing conservation and land management strategies, with a specific focus on areas of Saldanha Limestone Strandveld and managing threats to the region's remarkable botanical diversity.

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PART 3: References, Methodology, and Supplementary Information

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6. Appendix A: Plant Species List

The following lists all of the plant species that were recorded in the vegetation plots surveyed in the study area. Note that in a few instances plants could not be identified to species level and were thus given the epithet "spA".

- *Acacia cyclops*
- *Acacia saligna*
- *Agathosma bisulca*
- *Agathosma imbricata*
- *Agathosma serpyllacea*
- *Agathosma thymifolia*
- *Albuca canadensis*
- *Albuca spA*
- *Amphithalea ericifolia subsp. erecta*
- *Annesorhiza macrocarpa*
- *Annesorhiza spA*
- *Anthospermum spathulatum subsp. spathulatum*
- *Aspalathus hispida subsp. hispida*
- *Aspalathus ternata*
- *Asparagus aethiopicus*
- *Asparagus capensis var. litoralis*
- *Asparagus declinatus*
- *Asparagus fasciculatus*
- *Asparagus lignosus*
- *Asparagus ovatus*
- *Asparagus rubicundus*
- *Babiana ambigua*
- *Babiana spA*
- *Berkheya armata*
- *Berzelia abrotanoides*
- *Bulbine annua*
- *Carpobrotus edulis subsp. edulis*
- *Chaenostoma uncinatum*
- *Chasmanthe aethiopica*
- *Cheiridopsis rostrata*
- *Chironia baccifera*
- *Cissampelos capensis*
- *Cliffortia polygonifolia var. polygonifolia*
- *Clutia alaternoides var. alaternoides*
- *Clutia daphnoides*
- *Colchicum eucomoides*
- *Colpoon compressum*
- *Conicosia pugioniformis subsp. pugioniformis*
- *Cotyledon orbiculata var. orbiculata*
- *Crassothonna cylindrica*
- *Crassula expansa subsp. expansa*
- *Crassula muscosa*
- *Cyanella hyacinthoides*
- *Cynanchum africanum*
- *Cynorhiza typica*
- *Delosperma spA*
- *Dimorphotheca nudicaulis var. nudicaulis*
- *Diosma guthriei*
- *Diosma oppositifolia*
- *Diospyros austro-africana var. rugosa*
- *Dipogon lignosus*
- *Disparago ericoides*
- *Drimia elata*
- *Ehrharta villosa var. villosa*
- *Elegia elephantina*
- *Elegia microcarpa*
- *Elegia tectorum*
- *Erica bolusiae var. bolusiae*
- *Erica lasciva*
- *Erica plumosa*
- *Eriocephalus africanus var. africanus*
- *Eriocephalus racemosus var. racemosus*
- *Euclea racemosa subsp. racemosa*
- *Euphorbia burmannii*
- *Euphorbia caput-medusae*
- *Euphorbia mauritanica*
- *Euryops linifolius*
- *Ferraria crispa*
- *Ficinia dunensis*
- *Ficinia secunda*
- *Freesia viridis subsp. viridis*
- *Gazania rigens var. rigens*
- *Gladiolus caeruleus*
- *Grielum grandiflorum*
- *Gymnosporia buxifolia*
- *Haemanthus coccineus*
- *Helichrysum niveum*
- *Helichrysum revolutum*
- *Helichrysum teretifolium*
- *Indigofera platypoda*
- *Jordaaniella dubia*
- *Lachenalia bulbifera*
- *Lessertia spA*
- *Lessertia tomentosa*
- *Leucadendron cinereum*
- *Leucadendron salignum*
- *Leucospermum tomentosum*
- *Limonium acuminatum*
- *Limonium peregrinum*
- *Lotononis falcata*
- *Lycium amoenum*
- *Lycium ferocissimum*
- *Lycium tetrandrum*
- *Massonia longipes Baker*
- *Maurocenia frangula*
- *Maytenus lucida*
- *Melolobium exudans*
- *Metalasia densa*

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- *Microloma sagittatum*
- *Muraltia harveyana*
- *Muraltia spinosa*
- *Nenax hirta subsp. calciphila*
- *Olea exasperata*
- *Osteospermum moniliferum subsp. moniliferum*
- *Othonna gymnodiscus*
- *Othonna undulosa*
- *Oxalis compressa*
- *Oxalis hirta var. hirta*
- *Oxalis luteola*
- *Oxalis pes-caprae var. pes-caprae*
- *Oxalis versicolor var. versicolor*
- *Passerina corymbosa*
- *Pelargonium fulgidum*
- *Pelargonium gibbosum*
- *Pelargonium lobatum*
- *Pelargonium triste*
- *Pentameris spA*
- *Phylica cephalantha*
- *Phylica ericoides var. ericoides*
- *Polygala myrtifolia var. myrtifolia*
- *Pterocelastrus tricuspidatus*
- *Pteronia divaricata*
- *Pteronia onobromoides*
- *Pteronia uncinata*
- *Putterlickia pyracantha*
- *Restio impolitus*
- *Restio quinquefarius*
- *Restio spA*
- *Roepera flexuosa*
- *Roepera morgsana*
- *Romulea flava var. flava*
- *Romulea tabularis*
- *Ruschia macowanii*
- *Ruschia umbellata*
- *Salvia aurea*
- *Satyrium odorum*
- *Searsia glauca*
- *Searsia laevigata*
- *Senecio aloides*
- *Septulina glauca*
- *Serruria decipiens*
- *Staavia radiata*
- *Staberoha distachyos*
- *Stilbe ericoides*
- *Tetragonia fruticosa*
- *Thamnochortus punctatus*
- *Thamnochortus spicigerus*
- *Thesium confusum*
- *Thesium spinosum*
- *Trachyandra divaricata*
- *Trichocephalus stipularis*
- *Tylecodon grandiflorus*
- *Tylecodon paniculatus*
- *Wachendorfia paniculata*
- *Willdenowia incurvata*
- *Willdenowia sulcata*

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7. Appendix C: Methodology Desktop Phase

A desktop assessment was undertaken using an appropriate Geographic Information System (GIS) and the latest available spatial datasets, as well as relevant online biodiversity databases and/or literature (these are listed where applicable). The aim of this was to develop local digital cartographs and species lists/databases. The various subsections that follow expand upon this desktop assessment.

It must be noted that during the entirety of this project it was assumed that all third-party information used — e.g., GIS software and data, satellite imagery, mapping algorithms, etc. — was correct and accurate at the time of their use. The author of this report accepts no liability for any erroneous data or algorithms produced by any third-parties, or any subsequent products derived from such data.

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7.1. Vegetation Plot Clustering

Vegetation plot data were processed to construct a plant species matrix. To prepare for plot clustering, the species matrix was subjected to a Hellinger transformation, which reduces the effect of double zeros and is suitable for ecological community data. A Bray-Curtis dissimilarity matrix was then calculated from the Hellinger-transformed data. Finally, hierarchical clustering was performed on the Bray-Curtis dissimilarity matrix using Ward's D2 method and the data was partitioned into 6 clusters. All of these analyses were conducted in R Statistical Software (version 4.4.3 with package vegan).

7.2. Ecologically Important Landscape Features: Custom GIS Mapping

The GIS was used together with the latest Google Earth satellite imagery to delineate and map observable landscape features in the study area and surrounds. Specifically, attention was given to homogenous units that could easily be recognized. However, while satellite imagery is highly useful, it nevertheless suffers from several issues. For example, these include the generation of areas where image stitching has resulted in different colours for the same features, or imagery that might not have a high enough resolution, among other things. For this reason ground truthing is required to validate and refine the results of such desktop analyses.

7.3. GIS Remote Sensing and Statistical Modelling

This section outlines the remote sensing methodology employed to identify and map vegetation potentially associated with underlying limestone geological formations in the vicinity of Yzerfontein, Western Cape. The approach integrated cloud-based geospatial processing capabilities of Google Earth Engine (GEE) with desktop Geographic Information System (GIS) functionalities of QGIS, leveraging Python scripting for automation and analysis, as well as R Statistical Software.

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7.3.1. Data Acquisition

7.3.1.a) Satellite Imagery

Sentinel-2 Level-2A (Surface Reflectance) imagery, provided by the European Space Agency (ESA) through the Copernicus programme, was utilized as the primary data source. Sentinel-2 data offers a suitable balance of spatial and spectral resolution for vegetation and geological mapping. Specifically, the following bands were accessed:

- **Blue (B2):** 10 m spatial resolution
- **Green (B3):** 10 m spatial resolution
- **Red (B4):** 10 m spatial resolution
- **Near-Infrared (NIR, B8):** 10 m spatial resolution

Imagery was filtered for the period of 2024-07-01 to 2024-10-30 to capture peak vegetation vigour during the region's spring flower season, while also minimizing cloud cover (images with less than 10% cloudy pixel percentage were selected). A median composite of the available images within the specified period was generated to mitigate residual atmospheric effects and cloud/shadow contamination.

7.3.1.b) Digital Elevation Model (DEM)

A Digital Elevation Model (DEM) from the Copernicus DEM GLO-30 dataset was incorporated. This global 30-meter resolution DEM provides essential topographic information for terrain analysis, which can be indicative of underlying geological structures often associated with limestone.

7.3.1.c) Pre-processing and Feature Derivation

All initial data acquisition and pre-processing steps were performed within the Google Earth Engine (GEE) cloud computing platform, accessed via the QGIS Google Earth Engine Plugin and Python scripting.

A rectangular Area of Interest (AOI) was used that encompassed the region around Yzerfontein. All subsequent data processing and analysis were clipped to this defined AOI.

7.3.1.d) Image Compositing and Index Calculation

The following raster products were derived:

- **Sentinel-2 (NIR-R-G) Composite:** A false-colour composite was created by assigning the Near-Infrared (B8) band to the Red channel, the Red (B4) band to the Green channel, and the Green (B3) band to the Blue channel. This composite enhances vegetation visibility, with dense vegetation appearing in shades of red. The resulting composite has a spatial resolution of 10 meters.
- **Normalized Difference Vegetation Index (NDVI):** The NDVI was calculated using the Near-Infrared (B8) and Red (B4) bands of the Sentinel-2 imagery, as per the formula NDVI = (NIR + Red) / (NIR - Red).

The NDVI provides a standardized measure of vegetation greenness and density. Higher NDVI values indicate denser vegetation. The resulting NDVI raster has a spatial resolution of **10 meters**.

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7.3.2. Limestone and Vegetation Discrimination Techniques

The primary strategy for distinguishing limestone areas and associated vegetation relied on a combination of spectral and topographic characteristics:

- **Spectral Signatures of Vegetation:** Variations in NDVI values and the visual appearance in the NIR-R-G composite were used to identify different vegetation densities. It is hypothesized that vegetation growing on limestone might exhibit distinct spectral properties due to soil alkalinity, nutrient availability, or specific limestone endemic plant species. The shallow nature of soils in typical Saldanha Limestone Strandveld also mean vegetation is usually less dense.
- **Spectral Signatures of Limestone:** While direct mineralogical mapping requires hyperspectral data, the Short-Wave Infrared (SWIR) bands (B11, B12) of Sentinel-2 can offer some insights into lithological differences. Carbonate minerals, characteristic of limestone, exhibit specific absorption features in the SWIR region.
- **Topographic Analysis:** Areas characterized by specific limestone outcrops visible in the DEM and can provide indirect evidence of underlying Saldanha Limestone Strandveld.

7.3.3. Classification Approach

For the final classification and prediction of limestone vegetation, a supervised classification approach was used. This involved:

1. **Ground Truthing:** Collection of ground truth data through field surveys. This included polygons of known exposed limestone, and Saldanha Limestone Strandveld and associated types.
2. **Training Data Generation:** Using the collected ground truth data, training regions of interest (ROIs) were digitized and their respective pixel values extracted.
3. **Classifier Training:** A Random Forest machine learning classifier was trained using the spectral (Sentinel-2 bands, NDVI) and topographic (DEM) features extracted for the training ROIs.
4. **Classification:** The trained classifier was applied to the entire feature stack to produce a classified raster map delineating the presence of absence of “limestone associated vegetation”.
5. **Accuracy Assessment:** An independent set of validation points (not used for training) was to assess the accuracy of the classification.

7.3.4. Software

The following software platforms were used:

- Google Earth Engine (GEE): Cloud-based platform for accessing and processing satellite imagery and geospatial datasets.
- QGIS (Version 3.40.4-Bratislava): Open-source desktop GIS software for data visualization, management, and integration with GEE via the GEE Plugin.
- Python (with ee and ee_plugin libraries): For scripting and automating data access and processing workflows between GEE and QGIS.
- R Statistical Software (version 4.4.3 with packages terra, sf, RStoolbox, and caret): For advanced statistical analysis, machine learning classification, and accuracy assessment.

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7.3.5. Output

The final output of this process was a GeoTIFF raster file with predicted occurrences of Limestone Vegetation, which was then overlaid with hyper-saturated Google and ESRI satellite images to delineate the boundaries of Saldanha Limestone Strandveld and associated variations. This was also used in conjunction with a classification/clustering of the vegetation survey data, with the aim of distinguishing between various types of Saldanha Limestone Strandveld and other vegetation types. See Figure 7 for examples of the various GIS layers used and a snapshot of the final output.

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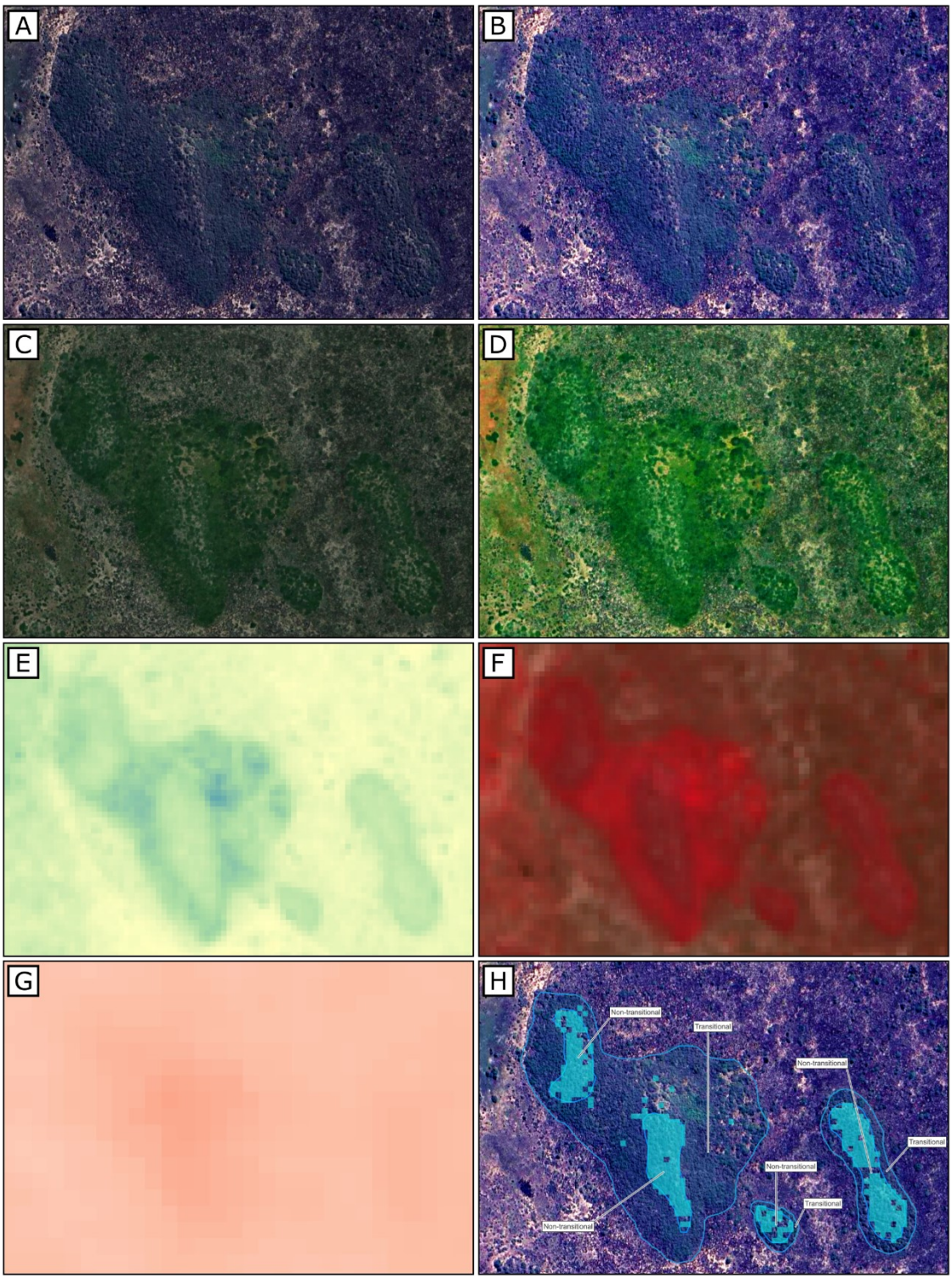

Figure 7: Example of the various GIS layers that were used in modelling and visual inspection for delineating Saldanha Limestone Strandveld and associated variations. The example has the same area in focus to illustrate how various insights can be gained depending on the GIS layer used. A) Regular Google Satellite image, B) hyper-saturated Google Satellite image, C) Regular ESRI Satellite image, D) hyper-saturated ESRI Satellite image, E) NDVI image, F) Near-Infrared-Red-Green [NIR-R-G] satellite image, and G) Digital Elevation Model (DEM). H) The final output of the random forest (RF) classification model showing the prediction of limestone occurrence (blue pixels) and subsequent delineation of non-transitional and transitional limestone plant community types.

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8. Appendix D: Methodology Fieldwork Phase

Briefly, the field surveys aimed to investigate the following on-site aspects, with a specific focus on Saldanha Limestone Strandveld:

- The occurrence of plant SCC;
- The occurrence of limestone indicator plant species;
- Specific vegetation types (identification, classification, and delineation).

8.1. Botanical Assessment Details

Surveying was done within specifically targeted areas that were perceived as ecologically distinct and/or sensitive based on the results obtained from the desktop assessment of plant community types. This was to optimize coverage and to perform a rapid, but efficient, vegetation and ecological assessment at each survey area.

The botanical assessment was conducted by surveying fixed-point plots of sufficient size within each community type, which were also supplemented with random meanders (South African National Biodiversity Institute, 2020) within the respective community types. The combination of single fixed-point plots, supplemented with random meanders, are highly efficient for conducting floristic analyses. This allows plant species coverages and SCC occurrences to be rapidly estimated, as well as the compilation of adequate plant species lists, thereby giving a prompt indication of botanical diversity. Other useful observations were also recorded within each community type, examples of which include ecological condition and current impacts (examples of which could include the presence of invasive alien plant species, livestock grazing, degree of erosion, etc.), general vegetation density and physiognomic characteristics, habitat notes, and the presence of any sensitive features (e.g., wetlands, seepages, and drainage lines) where applicable. Finally, any opportunistic observations were also made while surveying.

Various field guides and identification manuals were used for plant identification, as well as other relevant literature regarding the ecology of the region (Coates Palgrave, 2005; Dorrat-Haaksma & Linder, 2012; Johnson et al., 2015; Manning, 2007; Manning & Goldblatt, 2012; Manning & Helme, 2024; Saunders & Saunders, 2021; Schumann et al., 1992; Van Oudtshoorn, 2012), and are listed in section 5. Online databases such as iNaturalist (https://www.inaturalist.org/) was also used.

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9. Appendix E: Notes on SCC and Protected Plant Species

This section includes relevant definitions and regulations pertaining to SCC and protected plant species as determined by national legislation. Briefly, a permit is required to perform any restricted activity, as defined by NEM:BA, on specimens of any SCC or protected plant species, whether such specimens are living or dead. Note: this is NOT an exhaustive account of NEM:BA.

9.1. National Environmental Management: Biodiversity Act, 2004 (Act No. 10, 2004, Vol. 467, No. 26436)

NEM:BA Definition of "specimen" (Chapter 1, Definitions):

a) any living or dead animal, plant or other organism;

b) a seed, egg, gamete or propagule or part of an animal, plant or other organism capable of propagation or reproduction or in any way transferring genetic traits;

c) any derivative of any animal, plant or other organism; or any goods which-

   i. contain a derivative of an animal, plant or other organism; or

   ii. from an accompanying document, from the packaging or mark or label, or from any other indications, appear to be or to contain any derivative of an animal, plant or other organism.

NEM:BA Definition of "restricted activity" (Chapter 1, Definitions):

(a) in relation to a specimen of a listed threatened or protected species, means-

i. hunting, catching, capturing or killing any living specimen of a listed threatened or protected species by any means, method or device whatsoever, including searching, pursuing, driving, lying in wait, luring, alluring, discharging a missile or injuring with intent to hunt, catch, capture or kill any such specimen;
ii. gathering, collecting or plucking any specimen of a listed threatened or protected species;
iii. picking parts of, or cutting, chopping off, uprooting, damaging or destroying, any specimen of a listed threatened or protected species;
iv. importing into the Republic, including introducing from the sea, any specimen of a listed threatened or protected species;
v. exporting from the Republic, including re-exporting from the Republic, any specimen of a listed threatened or protected species;
vi. having in possession or exercising physical control over any specimen of a listed threatened or protected species;
vii. growing, breeding or in any other way propagating any specimen of a listed threatened or protected species, or causing it to multiply;
viii. conveying, moving or otherwise translocating any specimen of a listed threatened or protected species;
ix. selling or otherwise trading in, buying, receiving, giving, donating or accepting as a gift, or in any way acquiring or disposing of any specimen of a listed threatened or protected species; or
x. any other prescribed activity which involves a specimen of a listed threatened or protected species

Restricted activities involving listed threatened or protected species, Part 2, 57:

(1) A person may not carry out a restricted activity involving a specimen of a listed threatened or protected species without a permit issued in terms of Chapter 7 (Permits).

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9.2. National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004): Threatened or Protected Species Regulations

"**Biodiversity Act**" means the National Environmental Management: Biodiversity Act, 2004 (Act No. 10 of 2004), including any amendment thereof;

"**protected species**" means any species listed as protected in terms of section 56(1)(d) of the Biodiversity Act;

"**threatened species**" means an indigenous species listed as critically endangered, endangered or vulnerable species in terms of section 56(1)(a), (b) and (c) of the Biodiversity Act;

Chapter 2 (Permit System for Listed Threatened or Protected Species), Part 1 Application for permits: Carrying out a restricted activity

4. (1) A person may carry out a restricted activity involving a specimen of a listed threatened or protected species, only if he or she is the holder of a permit issued-

a) in terms of section 57(1) of the Biodiversity Act;
b) in accordance with Chapter 7 of the Biodiversity Act, and
c) in accordance with these Regulations;

unless the Minister has exempted the carrying out of such restricted activity involving such specimen in terms of section 57(4) of the Biodiversity Act.

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10. Appendix F: Abbreviated Curriculum Vitae of the Specialist

Personal Details:

- Name: Dr. Jan-Hendrik Keet
- Address: Somerset West, Western Cape, 7130
- Cell: 071 451 4853
- Email: info@ecofloristix.co.za
- Date of Birth: 07 November 1988
- Website: https://ecofloristix.co.za/

Expertise and Experience:

- Current: Botanical & Terrestrial Biodiversity Specialist Consultant (EcoFloristix Specialist Botanical Surveys)
- Current: Freelance Academic/Technical Editor, Proof-reader, and Dissertation Specialist
- Previous: Post-Doctoral Researcher — Mathematical Biosciences Hub (Department of Mathematics), Stellenbosch University
- Previous: Post-Doctoral Researcher — DST NRF Centre of Excellence for Invasion Biology (Department of Botany and Zoology), Stellenbosch University
- Specialization: Botany, Ecology, Biogeography, Invasive Plant Species, and Invasion Biology
- Years of experience: > 10 years
- Published in various, high-impact, national and international scientific journals

Skills and Competencies:

- Botany and Ecology
- Invasive Species Biology (PhD in Botany [Stellenbosch University] with a focus on Invasive Alien Plant Species and their environmental impacts)
- Plant Biogeography
- Plant Identification and Taxonomy
- Vegetation Surveys and Mapping
- Biodiversity Informatics
- Biological Sciences
- Soil Microbiome Composition, Function, and Chemistry
- Geographic Information Systems (*GISB1500S, NQF level 5*)
- Research Data Management and Data Visualization
- Statistical Computing Methods (*R Statistical Computing Expert*)
- Experimental Design and Analysis

Global Scientific Influence:

- Citations >650
- Global Publication Reads >9000
- Scopus h-index 11
- Google Scholar h-index 11
- Google Scholar i10-index 12

Tertiary Education:

- 2015 – 2019: Stellenbosch University, Stellenbosch, South Africa. Doctor of Philosophy (Botany)
- 2013 – 2014: University of the Free State, Bloemfontein, South Africa. Magister Scientiae (Botany)
- 2012: University of the Free State, Bloemfontein, South Africa. Bachelor of Science Honours (Botany) - *cum laude*

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- 2009 – 2011: University of the Free State, Bloemfontein, South Africa. Bachelor of Science (Chemistry with Physics and Biology) - *cum laude*

Employment History:

- 2015 – present: Botanical Specialist
- 2021 – present: Freelance Academic/Technical Editor, Proof-reader, and Dissertation Specialist
- 2019 – 2021: Post-Doctoral Researcher – Centre for Invasion Biology (Department of Botany and Zoology), Stellenbosch University
- 2011: Part-time demonstrator. Department of Plant Sciences, University of the Free State, Bloemfontein, South Africa
- 2010: Part-time lab assistant. Department of Chemistry, University of the Free State, Bloemfontein, South Africa
- 2007 – 2009: Shop Manager. Christian Tees, Brandwag Centre, Bloemfontein

Memberships, Certifications, and Short Courses:

- SACNASP: Professional Natural Scientist (No.: 121678)
- South African Association of Botanists (SAAB) Ordinary Member (No.: 821)
- SAGIC Invasive Species Consultant (Cape Town, South Africa), March 2016
- GIS Intermediate (NQF level 5): Hydrological modelling and terrain analysis using digital elevation models (University of the Free State, South Africa), 2014
- Project Management (Stellenbosch University), 2023
- Good Laboratory Practice seminar presented by Merck Millipore South Africa, 2012
- Laboratory Safety seminar presented by Merck Millipore South Africa, 2012
- Golden Key International Honour Society (Membership No.: 7564025), 2012

Selected Peer-reviewed Scientific Publications and Book Chapters (a full list is available on request)**:**

- **Keet J-H** & Hui C (2025) One-hectare fine-scale dataset of a fynbos plant community in the Cape Floristic Region. *Data in Brief*; https://doi.org/10.1016/j.dib.2025.111334
- Yannelli F, **Keet J-H**, Kritzinger-Klopper S, Le Roux JJ (2025) Legacy effects of an invasive legume more strongly impact bacterial than plant communities in a Mediterranean-type ecosystem. *Journal of Environmental Management* 373:123802, https://doi.org/10.1016/j.jenvman.2024.123802
- **Keet J-H**, Ellis AG, Hui C, Le Roux (2023) Responses of soil bacterial communities to invasive Australian *Acacia* species over large spatial scales. In: Richardson DM, Le Roux JJ, & Marchante E (Eds.) *Wattles: Australian Acacia Species Around the World*, CAB International, https://www.cabidigitallibrary.org/doi/10.1079/9781800622197.0000.
- **Keet J-H**, Datta A, Foxcroft LC, Kumschick S, Wilson JRU, Nichols GR, Richardson DM (2022) Assessing the level of compliance with alien plant regulations in a large African protected area. *Biological Invasions* 24: 3831 – 3844, https://doi.org/10.1007/s10530-022-02883-7.
- Warrington S, Ellis AG, **Keet J-H**, Le Roux JJ (2022) How does familiarity in rhizobial interactions impact the performance of invasive and native legumes? *Neobiota* 72: 129 – 156, https://neobiota.pensoft.net/article/79620/.
- **Keet J-H** & Richardson, DM (2022) A rapid survey of naturalized and invasive eucalypt species in southwestern Limpopo, South Africa. *South African Journal of Botany* 144: 339 – 346, https://doi.org/10.1016/j.sajb.2021.09.008.
- Novoa A, Foxcroft LC, **Keet J-H**, Pyšek P, Le Roux JJ (2021) The invasive cactus *Opuntia stricta* creates fertility islands in African savannas and benefits from those created by native trees. Scientific Reports 11: 20748, https://www.nature.com/articles/s41598-021-99857-x.
- **Keet J-H**, Ellis AG, Hui C, Novoa A, Le Roux JJ (2021) Impacts of invasive Australian acacias on soil bacterial community composition, microbial enzymatic activities, and nutrient availability in fynbos soils. *Microbial Ecology* 82: 704 – 721, http://dx.doi.org/10.1007/s00248-021-01683-1.
- **Keet J-H**, Robertson MP, Richardson DM (2020) *Alnus glutinosa* (Betulaceae) in South Africa: invasive potential and management options. *South African Journal of Botany* 135: 280 – 293, https://doi.org/10.1016/j.sajb.2020.09.009.

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- Wilson JRU, Datta A, Hirsch H, **Keet J-H**, Mbobo T, Nkuna KV, Nsikani MM, Pyšek P, Richardson DM, Zengeya TA, Kumschick S (2020) Is invasion science moving towards agreed standards? The influence of selected frameworks. *NeoBiota*, 62: 569 – 590, https://doi.org/10.3897/neobiota.62.53243.
- Novoa A, **Keet J-H**, Lechuga-Lago Y, Pyšek P, Le Roux JJ (2020) Urbanization and *Carpobrotus edulis* invasion alter the diversity and composition of soil bacterial communities in coastal areas. FEMS Microbiology Ecology 96(7): fiaa106, https://doi.org/10.1093/femsec/fiaa106.
- Le Roux JJ, Leishman MR, Cinantya AP, Gufu GD, Hirsch H, **Keet J-H**, Manea A, Saul W-C, Tabassum S, Warrington S, Yannelli FA, Ossola A (2020) Plant biodiversity in the face of global change. *Current Biology* 30: R371 – R392, https://doi.org/10.1016/j.cub.2020.02.066.
- Hirsch H, Allsopp MH, Canavan S, Cheek M, Geerts S, Geldenhuys CJ, Harding G, Hurley BP, Jones W, **Keet J-H**, Klein H, Ruwanza S, van Wilgen BW, Wingfield MJ, Richardson DM (2019) *Eucalyptus camaldulensis* in South Africa – past, present, future. *Transactions of the Royal Society of South Africa* 75(1): 1 – 22, https://doi.org/10.1080/0035919X.2019.1669732.
- Le Roux JJ, Hui C, Castillo ML, Iriondo, JM, **Keet J-H**, Khapugin, AA, Médail F, Rejmánek M, Theron G, Yannelli FA, Hirsch H (2019) Recent anthropogenic plant extinctions differ in biodiversity hotspots and coldspots. *Current Biology* 29(17): 2912 – 2918, https://doi.org/10.1016/j.cub.2019.07.063.
- **Keet J-H**, Ellis AG, Hui C, Le Roux JJ (2019) Strong spatial and temporal turnover of soil bacterial communities in South Africa's hyperdiverse fynbos biome. *Soil Biology and Biochemistry* 136: 107541, https://doi.org/10.1016/j.soilbio.2019.107541.
- Le Roux JJ, Ellis AG, Van Zyl L-M, Hosking ND, **Keet J-H**, Yannelli F (2018) Importance of soil legacy effects and successful mutualistic interactions during Australian acacia invasions in nutrient-poor environments. *Journal of Ecology* 106(5): 2071 – 2081, https://doi.org/10.1111/1365-2745.1296.
- **Keet J-H**, Ellis AG, Hui C, Le Roux JJ (2017) Legume–rhizobium symbiotic promiscuity and effectiveness do not affect plant invasiveness. *Annals of Botany* 119(8): 1319 – 1331, https://doi.org/10.1093/aob/mcx028.
- Le Roux JJ, **Keet J-H**, Mutiti B, Ellis AG (2017) Cultivation may not dramatically alter rhizobial community diversity or structure associated with rooibos tea (*Aspalathus linearis* Burm.f.) in South Africa. *South African Journal of Botany* 110: 87-96, https://doi.org/10.1016/j.sajb.2017.01.014.
- Le Roux JJ, Hui C, **Keet J-H**, Ellis AG (2017) Co-introduction vs ecological fitting as pathways to the establishment of effective mutualisms during biological invasions. *New Phytologist* 215(4): 1354 – 1360, https://doi.org/10.1111/nph.14593.
- Nsikani M, Novoa A, Van Wilgen B, **Keet J-H**, Gaertner M (2017) *Acacia saligna*'s soil legacy effects persist up to ten years after clearing: Implications for ecological restoration. *Austral Ecology* 42(8): 880 – 889, https://doi.org/10.1111/aec.12515.
- **Keet J-H**, Cindi D, Du Preez PJ (2016) Assessing the invasiveness of *Berberis aristata* and *B. julianae* (Berberidaceae) in South Africa: management options and legal recommendations. *South African Journal of Botany* 105: 288 – 298, https://doi.org/10.1016/j.sajb.2016.04.012.

Selected Conferences (a full list is available on request)**:**

- 46th South African Association of Botanists conference (Qwa-Qwa, South Africa), January 2020, ***Alnus glutinosa* (L.) Gaertn. [Black Alder]: *an emerging invader in South Africa***
- International Association for Food Protection (IAFP; Louisville, Kentucky, USA), July 2019.
- Ecological Society of America Conference, (New Orleans, Louisiana, USA), August 2018 **Invasive legumes dramatically impact soil bacterial community structures but not function**
- Legumes for Life Workshop (Stellenbosch, South Africa), May 2018 **Legume-rhizobium symbiotic promiscuity and effectiveness do not affect plant invasiveness**
- Fynbos Forum Conference (Swellendam, South Africa), July 2017 **Assessing the impacts of invasive legumes on soil conditions and microbial community composition in a biodiversity hotspot**
- 43rd South African Association of Botanists Conference (Cape Town, South Africa), January 2017, **Legume-rhizobium symbiotic promiscuity and effectiveness do not affect plant invasiveness** *Best PhD presentation*
- 43rd Annual Research Symposium on the Management of Biological Invasions Conference (Worcester, South Africa), May 2016, **Legume-rhizobium symbiotic promiscuity does not determine plant invasiveness**
- Evolutionary dynamics of tree invasions: drivers, dimensions, and implications for management (Stellenbosch, South Africa), November 2015
- Neobiota: 8th International Conference on Biological Invasions (Antalya, Turkey), November 2014, **Assessing the threat and potential for management of Berberis spp. (Berberidaceae) in South Africa**

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- 42nd Annual Symposium on the Management of Invasive Alien Plants (Karridene Beach Hotel, Durban, South Africa)
- XXth Association for the Taxonomic Study of the Flora of Tropical Africa International Conference (Stellenbosch, South Africa), January 2014
- 41st Annual Symposium on the Management of Invasive Alien Plants (Cape St. Francis, South Africa), May 2013

Selected EIAs and other works (a full list is available on request)**:**

- Invasive Alien Plant Species Management Framework for the East London Industrial Development Zone (IDZ), East London, Eastern Cape Province, South Africa (June 2025). Report prepared for AGES. Reference: PR.25.017.
- Terrestrial Desktop Sensitivity for a Prospecting Right Application on Farm 622 for Uranium ore in the Namaqualand Magisterial District in the Northern Cape Province, South Africa (May 2025). Report prepared for Greenmined Environmental. Reference: PR.24.016.
- Terrestrial Desktop Sensitivity for a Proposed Prospecting Right On Farm Kamaggas no. 200, Drie Rivier No. 268, Polly's Kloof No. 267, Sannagas No. 269, and Klipfontein no. 266, for Uranium Ore in the Northern Cape Province, South Africa (May 2025). Report prepared for Greenmined Environmental. Reference: PR.24.018.
- Terrestrial Desktop Sensitivity for a Prospecting Right Application for Targeted Blocks on Farms Tusschen In 143, Aardvark 164, Steenbok 165, and Gifkop 166 near Steinkopf, Northern Cape Province, South Africa (May 2025). Report prepared for Greenmined Environmental. Reference: IA.25.006.
- Terrestrial Biodiversity Impact Assessment / Plant Species Impact Assessment for an industrial development on the proposed expansion of the bulk water pipeline on Portion 1 of Farm La Parisa No. 888, Paarl, Western Cape Province (May 2025). Report prepared for Doug Jeffrey Environmental. Reference: IA.25.003.
- Plant Species and Terrestrial Biodiversity Compliance Statement for illegal repairs to an old road through a watercourse and the removal of material from a water impoundment dam near Infanta, Western Cape (April 2025). Report prepared for EarthGrace. Reference: IA.25.016.
- Invasive Alien Species Risk Analysis Review of the Canetsfontein Wine Farm I&AS Risk Assessment Report (November 2024). Report prepared for Earthguard Consulting.
- (November 2024). Report prepared for Doug Jeffrey Environmental.
- Terrestrial Biodiversity and Plant Species Compliance Statement for a mining permit application project on Bonne Esperance Farm 83 near Tulbagh in the Western Cape Province (November 2024). Report prepared for Greenmined Environmental. Reference: IA.24.023.
- Section 24G Botanical Assessment for the construction of two unlawful dams on Farm 497 Portion 3 Weltevreden, Western Cape Province. Report prepared for Doug Jeffery Environmental (November 2024). Report prepared for Doug Jeffrey Environmental. Reference: IA.24.021.
- Invasive Alien Species Risk Analysis Review of the Canetsfontein Wine Farm I&AS Risk Assessment Report (November 2024). Report prepared for Earthguard Consulting.
- N6 Galway City (Ireland) Ring Road Environmental Impact Assessment Report: Assistance with Data Analysis, Modelling, and Validation (July 2024 – January 2025). In collaboration with Scott Cawley, Ireland.
- Terrestrial Biodiversity and Plant Species Compliance Statement for a mining permit application project on Bonne Esperance Farm 83 near Tulbagh in the Western Cape Province (November 2024). Report prepared for Greenmined Environmental. Reference: IA.24.023.
- Invasive Alien Species Risk Analysis Review of the Canetsfontein Wine Farm I&AS Risk Assessment Report (November 2024). Report prepared for Earthguard Consulting.
- Plant and Terrestrial Biodiversity Assessment for a Mining Permit Extension application for the mining site Norrabees near Henkries, Northern Cape Province (May 2024). Report prepared for Site Plan Consulting. Reference: IA.24.010A.
- Plant and Terrestrial Biodiversity Assessment for a Mining Permit Application for the mining site Spodumene Kop near Henkries, Northern Cape Province (May 2024). Report prepared for Site Plan Consulting. Reference: IA.24.010B
- Terrestrial Biodiversity (Fauna, Flora and Terrestrial Biodiversity) study and impact Report for the Grid Connection Solution for the Proposed Onderstepoort Solar 1 and 2 Facilities Near Boshoek in the North West Province. In collaboration with Nkurenkuru Ecology and Biodiversity (PTY) Ltd. (April 2024). Report prepared for Atlantic Energy Partners.

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- Specialist Invasive Alien Plant Species Assessment. (March 2024). Report prepared for Mpact Corrugated. Reference: IA.24.006.
- Terrestrial Biodiversity (Fauna, Flora, and Ecological EIA Phase Assessment) Report for the Proposed Kingston Solar PV Energy Facility Near Bothaville, Free State Province. In collaboration with Nkurenkuru Ecology and Biodiversity (PTY) Ltd. (March 2024). Report prepared for Atlantic Energy Partners.
- Terrestrial Biodiversity (Fauna, Flora, and Ecological EIA Phase Assessment) Report for the Proposed Crecy Photovoltaic Solar 4 Energy Facility and Associated Infrastructure near Mookgopong, Limpopo Province. In collaboration with Nkurenkuru Ecology and Biodiversity (PTY) Ltd. (February 2024). Report prepared for Atlantic Energy Partners.
- Plant and Terrestrial Biodiversity Assessment for a Solar Photovoltaic Facility near Northam, Limpopo. In collaboration with Nkurenkuru Ecology and Biodiversity (PTY) Ltd. (November 2023). Report prepared for Atlantic Energy Partners.
- Botanical Impact Assessment for a proposed rerouting of a sewer pipeline on Erf 5076, Khayalethu, Knysna, Western Cape. In collaboration with Keep Rooted (PTY) Ltd. (October 2023). Report prepared for Ohana Environmental. Reference: IA.23.015.
- Screening report for a proposed Solar PV plant near Boshoek, Northwest Province. In collaboration with Nkurenkuru Ecology and Biodiversity (PTY) Ltd. (September 2023). Report prepared for Atlantic Energy Partners.
- Plant and Terrestrial Biodiversity Assessment for a Powerline Corridor near Boshoek, Northwest Province. In collaboration with Nkurenkuru Ecology and Biodiversity (PTY) Ltd. (September 2023). Report prepared for Atlantic Energy Partners.
- Botanical Assessment and Motivation for a Mining Stockpile Area within a non-CBA zone on Farm Steinkopf no. 22 near Steinkopf, Northern Cape. (August 2023). Report prepared for Greenmined Environmental. Reference: IA.23.010.
- Botanical Impact Assessment: Development of portion 223 of Farm 559, Betty's Bay, Western Cape. (July 2023). Report prepared for Ohana Environmental. Reference: IA.23.007.
- Botanical Study and Assessment for a Housing Development, 2023. Proposed development of the development of Erf 397, Suiderstrand, Western Cape. Report prepared for RMS Environmental.
- Botanical Study and Assessment for a Mining Permit Application, 2023. Proposed development of a dolerite mine near Beaufort West, Western Cape. Report prepared for Greenmined Environmental (Pty) Ltd.
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2022. Full Botanical Assessment for the proposed development of wind energy facilities south of Bethal, Mpumalanga Province.
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2021. Application (Expansion of mining footprint), and Final Basic Assessment and Environmental Management Plan for the proposed sand mine expansion on Portion 4 of the Farm Zandberg Fontein 97, Western Cape Province.
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2021. Proposed development of wind energy facilities on the farms Brussels, Driepoort (664-1 and 664-2), Kameelfontein, Lisbon, Nazareth, and Zwartkrans, near Vryburg, Northwest Province.
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2021. Botanical Study and Assessment: Proposed development of wind energy facilities on the farm Kluitjieskraal, Loeriesfontein, Northern Cape Province.
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2021. Botanical Study and Assessment: Proposed development of an access road to the authorised Sutherland 1 and Rietrug wind energy facilities near Sutherland.
- Specialist Botanical Assessment Report: Assessment of Damage and Rehabilitation Costs for Unauthorised Driving of a 4x4 Vehicle in the Big Bay Open Space System, Cape Town. Prepared for Hannes, Pretorius, Bock & Bryant Attorneys.
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2019. Mining Permit, Final Basic Assessment & Environmental Management Plan for the proposed mining of Sillimanite, Aggregate and Stone Gravel on the Farm Koenabib 43, Northern Cape Province. Botanical Study and Assessment Report. Unpublished report prepared by Nkurenkuru Ecology and Biodiversity for GreenMined Environmental. Version 1.0, 30 January 2020
- In collaboration with Nkurenkuru Ecology and Biodiversity, 2019. Mining Permit, Final Basic Assessment & Environmental Management Plan for the proposed mining of Sillimanite on the Farm Wortel 42, Northern Cape Province. Botanical Study and Assessment Report. Unpublished report prepared by Nkurenkuru Ecology and Biodiversity for GreenMined Environmental. Version 1.0, 30 January 2020
- Specialist Invasive Alien Plant Species Report: Prepared for: Mpact Corrugated, Kuils River (Western Cape), July 2019

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- Proposed Township development, Country view, Gauteng: Biodiversity Impact Assessment (Flora) – Specialist Report prepared for Zone Land Solutions (PTY) Ltd, July 2015
- Colenso Anthracite Coal Mining and Power Station Project: Biodiversity Impact Assessment (Flora) – Specialist Report prepared for Zone Land Solutions (PTY) Ltd, July 2015

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