Open historical aerial photography in Australia: Scale, coverage, and utility

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Key points

- Applications of historical aerial photography (HAP) in catchment management are briefly reviewed.
- Metadata from 4 Australian HAP collections (Geoscience Australia, NSW, TAS and QLD) is integrated into a single database.
- 95.4% of continental Australia has some HAP coverage and populated coastal regions have been repeatedly resurveyed, but only ~23% has fine-scale (1:25,000 or finer) coverage suitable for detailed channel or vegetation work.
- Insufficient reporting of image quality metrics prevents a thorough assessment of the imagery's utility for catchment management applications.

Abstract

Australia's historical aerial photography (HAP) constitutes one of the country's longest-running environmental records, but it is dispersed across federal and state agencies with distinct catalogues and licence terms. This study presents the first synthesis of Australian HAP metadata. Records from four catalogues were combined to create a single database of 29,331 surveys spanning 1928 to 2019. Coverage is near-complete at coarse scales (95.4% of the continent) but drops to roughly 23% at the 1:25,000 threshold needed for detailed geomorphic and vegetation work, with the finest imagery concentrated in populated coastal regions. The synthesis demonstrates that cross-agency integration is tractable, though inconsistent quality reporting across catalogues constrains a full assessment of the imagery's utility.

Introduction

Aerial photographs have been collected from as early as the 1930s, with systematic mapping missions starting in the 1940s. Historical aerial photography (HAP) thus provides a unique record of landscape change at higher spatial resolution and over longer time spans than satellite imagery. Australia's collection, held by Geoscience Australia and state agencies, is among the country's largest environmental datasets. The challenge of working with HAP is that the imagery contains distortions and is difficult to accurately georeference and the spatio-temporal coverage is patchy.

Because aerial surveys were typically commissioned for mapping, defence, and land administration rather than for environmental research, their timing and location were driven by considerations unrelated to any question later asked of the imagery. back further than any other form of remotely sensed data: reliable satellite observation begins only with Landsat in the 1970s, whereas systematic aerial survey extends back to the 1940s with some imagery collected as early as 1926 (Coghlan & Mills, 2026). Purpose-built environmental monitoring, by contrast, is overwhelmingly a product of recent decades, and genuinely long-term records remain rare (Tomscha et al., 2016). By pushing the observational baseline back before the satellite era, HAP helps to counter this recency bias and to place present-day environmental change in a longer historical context (Morford et al., 2024). Its coverage is, admittedly, uneven — shaped by the same administrative priorities that produced it (see Results) — but that unevenness is arguably independent of the environmental processes now studied through it (Davies et al., 2018).

Uses of HAP

HAP has found wide application across the environmental sciences. In fluvial geomorphology, it has been used to reconstruct planform changes over decadal to century timescales (Erskine, 2011; Gurnell, 1997; Hughes et al., 2006) and to examine the biogeomorphological influence of riparian vegetation on channel form (Mabbott & Fryirs, 2022). Terrestrial vegetation dynamics have been studied extensively using HAP in Australia, as reviewed by Fensham & Fairfax (2002), who found applications ranging in scale from individual tree crowns to regional landscapes.

Structure-from-motion algorithms applied to overlapping HAP frames can yield 3D terrain models, enabling volumetric reconstruction of landscape change (Feurer & Vinatier, 2018; Knuth et al., 2023). A recent mixed-method study compared quantitative change measures derived from HAP with oral histories from land managers (Mohr et al., 2024). Most recently, advances in computer vision have opened the possibility of automated large-scale orthorectification (Knuth et al., 2023; Maiwald et al., 2023; Noda et al., 2024) and automated image interpretation for change detection, including machine learning studies of riparian vegetation change (Afzali & Rusnák, 2025) and forest cover change (Morford et al., 2024).

The studies above can be broadly distinguished by how they use temporal information. Some treat HAP as evidence of a past *state* — a baseline against which the present can be compared. Others, including Gurnell (1997) and Mabbott & Fryirs (2022), use it as evidence of historical *processes*, comparing multiple epochs to reconstruct rates and directions of change. Process studies impose more demanding data requirements: imagery must exist at several points in time, each meeting a resolution threshold sufficient to detect the changes of interest. The analytical value of HAP for such studies is therefore a function of the density and span of the multi-epoch record, which motivates an understanding of where that record exists, at what scales, and across what time spans.

Licencing of collections

Geoscience Australia holds the largest collection of historical aerial photographs in Australia and has invested significantly in the digitisation of its entire collection. Older photographs whose copyright has expired are in the public domain; the remainder Geoscience Australia releases under a Creative Commons licence.

NSW, QLD, Tasmania, and the ACT have all released HAP metadata under Creative Commons licences. The ACT Government publishes its historic aerial photo footprints through ACTmapi. The ACT collection was not analysed in this study: it is a small collection that is expected to be fully redundant with Geoscience Australia's holdings, which provide national coverage including the ACT. In SA, NT, VIC and WA, imagery is made available under commercial terms. Digital imagery metadata is available for each of these states, though licencing terms vary.

Quality criteria

To study how rivers change over time requires imagery of sufficient quality to detect genuine geomorphic or vegetation change against the background of errors inherent in data extraction and registration. A fundamental question when designing such studies is therefore what kind of imagery is needed — specifically, what spatial resolution or scale is required to reliably represent the process being studied? To explore how researchers have approached this in practice, the author reviewed a selection of river management studies that have used historical aerial photography.

Historical aerial photographs have been used to document river channel change, yet the criteria applied by researchers to assess and report the quality of their photographic sources vary considerably. Erskine (2011) provides no explicit quality criteria for the aerial photographs used in his study of the lower Pages River, defining accuracy by the output map product rather than the input imagery. Gurnell (1997), by contrast, applied scale as an active selection criterion in her study of the River Dee and quantified registration error explicitly. Mabbott & Fryirs (2022), working on the Allyn River, similarly characterised imagery quality through georeferencing accuracy, though they do not report the scale of the photographs used. Together these studies illustrate that there is no consensus in the fluvial geomorphology literature on how the quality of historical aerial photography should be assessed or reported, with authors variously prioritising scale consistency, registration error, or output map accuracy.

The most methodologically detailed quality reporting appears in studies that employ digital processing pipelines. Afzali & Rusnák (2025), the most recent fluvial geomorphology application reviewed here, reported both photograph scales and a final orthorectified pixel resolution, reflecting the requirements of machine-learning workflows and the capacity of digital methods to impose consistent processing standards. Similarly, Morford et al. (2024) and Knuth et al. (2023) characterised their imagery by Ground Sampling Distance (GSD). These studies share a common trait: GSD is reported as an explicit quality criterion rather than a by-product of analogue scale.

Given the inconsistency of quality reporting in the broader literature, and the absence of GSD or scan-resolution metadata from the Australian catalogues examined here, this study adopts photograph scale as a proxy for imagery utility. Thresholds of 1:25,000 and 1:50,000 are used as indicative boundaries: surveys at or finer than 1:25,000 are broadly sufficient for detailed channel or vegetation feature extraction, while those coarser than 1:50,000 are of limited utility for such applications. These thresholds represent a pragmatic compromise given that GSD cannot be ascertained from catalogue metadata alone.

This study

Integrating HAP data across multiple government agencies requires occupying a vantage point that no single agency has structural incentive to occupy. Each collection has been developed and maintained within a distinct institutional remit, with no mechanism for researchers or practitioners to query across them in a coordinated way. This study demonstrates that such cross-agency synthesis is tractable, and that the resulting consolidated picture of national coverage constitutes a public good of a kind that academic research is well placed to produce.

This study has two aims. First, to demonstrate that openly-licensed HAP metadata from four Australian agencies can be integrated into a single dataset. Second, to map where in Australia HAP coverage exists, how far back in time it reaches, and how the coverage has accumulated decade by decade. With reference to the methods of published papers from the catchment management literature, this study aims to spatially map where different types of study may be possible.

Methods

What hasn't been digitised

Due to the gradual way in which the photographs are digitised, the data available through digital databases is a subset of each of the collections. In the case of each of the collections closely analysed by this study, the majority of all data has been digitised. However, undigitised data is handled in a different way by Geoscience Australia compared to the state collections. Geoscience Australia's catalogue represents all frames in its collection regardless of digitisation status, using georeferenced flight-line diagrams to provide spatial discoverability for both digitised and undigitised material (Geoscience Australia, 2024).

Reporting of scale

Several steps in the process of digitising and distributing aerial imagery may degrade the effective ground sampling distance (GSD) of the data available to researchers, independent of the scale at which the original photographs were captured. Scale — the ratio of image distance to ground distance, conventionally expressed as 1:N — is a property of the original analogue photograph, determined by the camera's focal length and the aircraft's flying height. GSD, by contrast, depends on both the original film scale and the resolution of the digital scan. These are not equivalent: a photograph collected at a fine scale may be available only as a coarse scan, yielding a GSD that does not reflect the original capture quality.

In many cases the original photo negatives were archived, allowing the capture of high-fidelity digital scans. Where digitisation projects must work from prints rather than negatives, the resulting digital product is a lower-fidelity copy of the original capture. None of the four catalogues reports GSD or scan resolution in a consistent, well-documented form, so analogue scale is the only resolution proxy available from catalogue metadata, and this analysis uses it as such.

The issue of spatial precision

HAP was collected before precision GPS. Location of the centroid of frames was approximated from flight logs and with reference to topographic maps. This process was not accurate by modern standards and further error could be introduced by digitisation of this metadata. Coordinates of individual frames cannot be treated as accurate. This analysis is undertaken at the level of the extent of the survey. Analysis at this scale is robust to imprecision of individual coordinates.

Spatial analysis of coverage

Survey records were compiled from four openly licensed government catalogues: Geoscience Australia's *HAP_Photo_Centres* geodatabase (Commonwealth Of Australia (Geoscience Australia) et al., 2026) (GA; national coverage), the NSW *Historical Image Index* (NSW Government Department of Customer Service, 2025), Queensland's *Imagery Project Extents* (Department of Natural Resources and Mines, Manufacturing and Regional and Rural Development, 2025), and Tasmania's *OpenDataWFS* layer 46 (Land Tasmania, n.d.). Each catalogue was processed to yield one polygon per survey — a discrete acquisition mission — using the most direct geometry pathway available.

QLD publishes one native project-extent polygon per survey; these were used without modification. **NSW** and **TAS** publish per-frame footprint polygons; frames were grouped by survey identifier (NSW: mission field; TAS: PROJECT_ID) and dissolved by union. Frames lacking a mission code were first sub-grouped by film roll and year to prevent unrelated flights from being amalgamated into a single multi-polygon.

GA (Coghlan and Mills, 2026) publishes approximately 1.2 million individual photo-centre points. Oblique and trimetrogon frames were excluded. Footprints were estimated from centroids by assuming an axis-aligned square footprint with side length proportional to a standard aerial photography film format (0.23 m) multiplied by the scale denominator; orientation error is negligible for cardinal flights and bounded for diagonal flights given typical inter-frame overlaps. Frames lacking a scale value were assigned the group median; groups with no median scale were excluded entirely. 11% of GA's frames were excluded for not reporting scale.

The four sources were joined into a single file of 29,378 surveys. Surveys outside the continental Australian bounding box were excluded to remove offshore-territory entries. The filtered dataset comprised **29,331 surveys**.

Coverage is represented as a simple polygon. For each figure, the relevant subset of survey polygons is dissolved using a union operation so that overlapping footprints are merged into a contiguous coverage geometry. A location is either covered by at least one survey or not. This approach sidesteps duplication complications: because overlapping polygons are merged rather than summed, multiple catalogue entries covering the same ground, and duplicate surveys held by both the commonwealth and state archives, do not inflate reported area. Summary statistics are computed by intersecting the dissolved coverage polygon with the Australian land boundary.

Results

Coverage through time

Figure 1 maps HAP coverage decade by decade from the 1930s to the 1990s, with a final panel showing total coverage across all time. Each panel shows the dissolved footprint of all surveys whose acquisition year falls within the decade; coverage is binary. Two patterns are apparent across the sequence.

First, the Commonwealth undertook substantial systematic mapping in the 1940s and 1950s. By the end of the 1950s, surveys already covered most of populated and coastal Australia, giving those areas a continuous record spanning seventy to eighty years. Coverage reaches its greatest decadal extent in the 1960s and 1970s, with the area tapering through the 1980s and 1990s. This taper most likely reflects the transition from airborne photographic survey to satellite imagery and digital orthophoto programmes from the 1980s onwards.

Second, the spatial bias toward populated coastal areas is evident through the decades. The heavily-mapped regions of the all-time panel were not photographed once and abandoned: they were re-surveyed repeatedly over successive decades, producing dense multi-temporal stacks along the eastern seaboard and the south-eastern agricultural zone. 95.4% of Australia is covered by at least one survey; the uncovered area is in the interior of the continent.

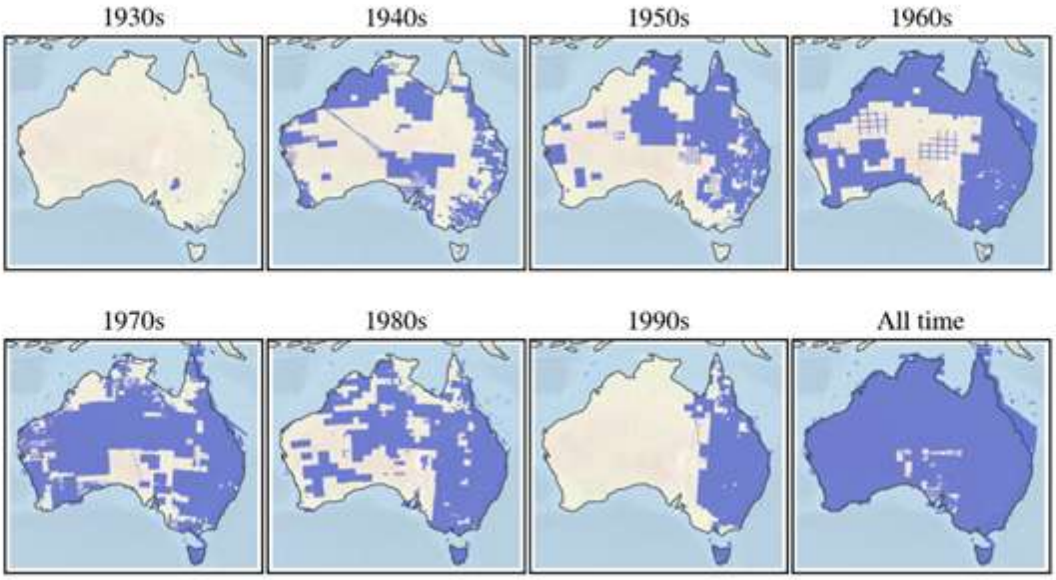

Figure 1 Decadal HAP coverage maps, 1930s–1990s. Decadal HAP coverage, 1930s–1990s, with total coverage across all time shown in the final panel. Each panel shows the dissolved binary coverage footprint for surveys whose acquisition year falls within the indicated decade. Survey polygons: Geoscience Australia photo centroids (footprint estimate, CC BY 4.0); NSW Historical Image Index (frame footprint union, Creative Commons); QLD Imagery Project Extents (native polygons, CC BY 4.0); TAS Aerial Photography Centers (frame footprint union, CC BY 3.0 Australia). CRS and projection: GDA2020 / Australian Albers (EPSG:9473)

Earliest fine-scale coverage

Figure 2 maps, for each location, the earliest decade in which any fine-scale survey arrived. Three scale thresholds are shown as separate panels: 1:25,000, 1:50,000, and 1:100,000. As established in the introduction, scale stands in as a proxy for imagery utility: surveys at 1:25,000 or finer are broadly sufficient for detailed channel or vegetation feature extraction, while imagery coarser than 1:50,000 is of limited use for such applications. Within each panel, surveys are grouped by decade, dissolved into a coverage polygon per decade, and rendered as fully opaque stacked layers — oldest decade on top —

with colours sampled from the turbo colour ramp (purple for the earliest decades, red for the most recent). The colour visible at any location therefore shows the earliest decade in which fine-scale coverage arrived there.

The three thresholds produce strikingly different coverage extents. At 1:100,000, approximately 95.3% of Australian land has at least one qualifying survey — essentially identical to total HAP coverage, since most surveys in the archive were flown at scales of 1:80,000 or finer. At 1:50,000 this falls to approximately 74.3%, and at the strictest 1:25,000 threshold only approximately 23.3% of land qualifies. In every case, the earliest qualifying surveys reach back to the 1930s, concentrated in populated and coastal areas.

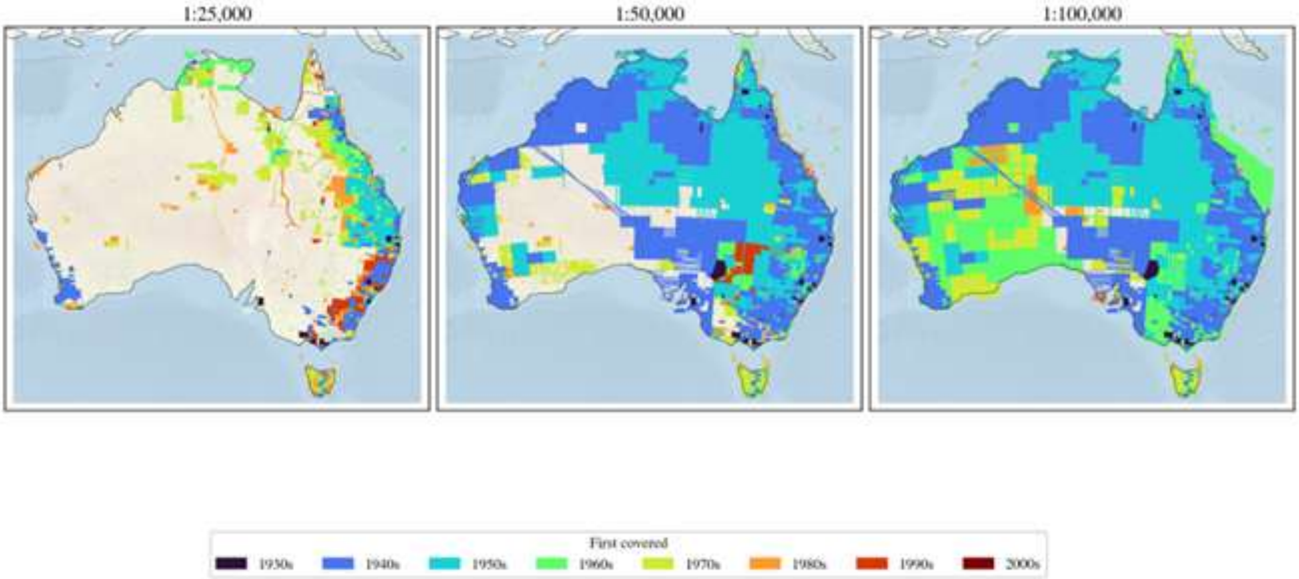

Figure 2. Earliest decade of fine-scale HAP coverage at three scale thresholds. Earliest decade of fine-scale HAP coverage at three scale thresholds (1:25,000, 1:50,000, 1:100,000). Per-decade survey polygons are dissolved and stacked as opaque layers; the colour at each location shows the earliest decade in which coverage arrived. Locations with no qualifying survey are left blank. Sources as for Figure 1

Discussion

A limitation of the catalogue metadata is that the scale of digitised imagery is reported for the original acquisition rather than the digital image available. This complicates the planning of HAP research. Furthermore, reporting of image quality in the reviewed HAP studies was found to be inconsistent. This situation is complicated by the evolution of methods of analysis: from studies using analogue techniques to project imagery over maps (Erskine, 2011), to studies where researchers manually georeference individual images (Gurnell, 1997; Mabbott & Fryirs, 2022), to studies that leverage modern computer vision methods to accurately orthorectify imagery (Afzali & Rusnák, 2025). How accuracy is conceived and reported has changed as methods have evolved. This study echoes Liu and Yang (2026) whose review of international literature using HAP called for clearer reporting of method. Nevertheless, this study has shown that the different collections can be integrated and that they support rather than duplicate each other.

The increasing feasibility of automated image alignment and georeferencing (Knuth et al., 2023; Maiwald et al., 2023; Noda et al., 2024) opens several near-term possibilities. Two-dimensional applications appear most tractable: catchment-scale reconstruction of historical gully erosion rates over time spans approaching a century, and automated riparian vegetation assessment (Afzali & Rusnák, 2025) or channel planform analysis (Erskine, 2011) of the kind undertaken by Mabbott & Fryirs

(2022), but at greater scale. Three-dimensional topographic change in rivers remains less likely in the near term, given the lack of methodological precedent.

If licensing of the metadata for non-open state collections can be arranged, it would be worthwhile to repeat this study at a national scale. Future HAP studies would benefit from a published, standardised dataset for easy discovery. If such a dataset reported GSD instead of analogue scale at collection, it would greatly facilitate research by allowing users to assess available imagery on a comparable metric. Such a dataset could be hosted as a platform that interfaces with each of the agencies' open collections. Future HAP studies using digital methods should report the GSD of imagery so that methodological requirements are clear.

Modern digital methods are making HAP more accessible. Land managers unskilled in GIS or computer vision, who don't have time to query complex databases or search archives, will increasingly have access to this long-term environmental dataset. The author's ongoing research investigates the implications of this.

Conclusions

This study has demonstrated that HAP catalogues can be integrated across different agencies. Due to inconsistencies in the way that scale is reported in the catchment management literature and limitations of the published collection metadata, it was not possible to make a spatial analysis of which types of studies are feasible where. Broadly speaking, spatio-temporal distribution of fine scale HAP has direct implications for the kinds of multi-temporal studies that are feasible. Fine-grained applications — channel planform reconstruction in the mould of Erskine (2011) or Mabbott & Fryirs (2022), or riparian vegetation analyses like Afzali & Rusnák (2025) — typically require imagery at 1:25,000 or finer. The 1:25k panel of Figure 2 therefore defines the realistic operating envelope for such work. Coarser applications — broad land-cover change, regional vegetation extent, or basin-scale geomorphic context — can draw on the near-complete 1:100,000 record.

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