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A Technical Report for

PROJECT MAHAMPY: PHASE II

Investigating the effects of harvesting techniques on *mahampy* regrowth and regrowth given a fire event, and using drone imagery to assess *mahampy* wetland health

September 2023

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1 Overview

Wetland habitats within Madagascar play an important role both ecologically and economically. Globally, freshwater ecosystems are amongst the most vulnerable, with the 2020 Living Planet Index (LPI) reporting an 84% decline in freshwater populations since 1970 (WWF, 2020). Freshwater ecosystems support a disproportionately high amount of biodiversity and provide valuable ecosystem services such as carbon sequestration and flood abatement (Zedler and Kercher, 2005). Madagascar has been recognised as a global hotspot of freshwater biodiversity with high levels of endemism (Benstead et al., 2003). Furthermore, in Madagascar, wetlands provide the raw materials needed for making products such as mats and baskets, as well as being used for housing and cooking fuel (Andrianadrasana et al., 2005). Despite this importance, Madagascar's wetlands have received little research attention and are declining faster than its forests, with some regions in Madagascar losing over 60% of wetland coverage since 1960 (Bamford et al., 2017).

In Sainte Luce, a rural, coastal community in the Anosy region of southeast Madagascar, the wetland reed *Lepironia mucronata,* known locally as *mahampy*, is harvested by women and used as a weaving material. Culturally, *mahampy* is of great importance as it provides a traditional livelihood opportunity to women in Sainte Luce. *Mahampy* is important economically as selling products crafted from *mahampy* forms a vital source of income, particularly where there is little to no access to formal employment (International Monetary Fund, 2023). However, unsustainable resource use is likely to lead to declines in *mahampy* reedbeds, impacting the livelihoods of the people who depend on them. In the Mekong delta, Vietnam, the use of cutting reeds for harvest is banned as it is believed to be detrimental to reedbed health (Triet, 2010). In the KwaZulu-Natal province of South Africa, it is believed that cutting reeds impedes regrowth (Traynor et al., 2010). However, neither example involved an explicit comparison of harvesting techniques. There has been little research carried out in Madagascar on the impacts of various harvesting techniques on *mahampy* reedbed health.

Within the wetlands found in Sainte Luce, two different techniques are used to harvest *mahampy* stems: either individual stems are pulled out of the rhizome, or a bundle of stems are cut near the base using knives. Women from the community of Sainte Luce harvest reeds by pulling, where they selectively harvest the longest stems, which are needed for weaving mats. However, it has been reported that women from neighbouring communities using the same reedbeds prefer to harvest by cutting the reeds. This enables them to rapidly collect multiple stems and maximise productivity when working in the reedbeds, but results in harvesting stems that are too short to weave and are subsequently discarded. Although the plant would be expected to produce new stems as long as the rhizome is left intact, few studies have directly compared the effect of different harvesting techniques on reed growth.

Fire is also a factor that impacts *mahampy* wetlands, but the effects of burning on wetland habitats is relatively understudied (Kotze, 2013). Species with underground rhizomes, such as *Lepironia*, are expected to be able to resist fire by resprouting following disturbance. However, it is not known how fire events affect *Lepironia* growth. Drier conditions have been shown to influence the severity of fires (Kotze, 2013), therefore understanding the response of wetlands to fire is especially important in the context of severe and chronic droughts which are occurring with higher frequency in southern Madagascar (UNICEF, 2022). In Madagascar, fire is also commonly used as a management tool for agricultural purposes, using a technique known as *tavy*[1], and can spread to adjacent areas including wetlands. Fires can therefore occur both naturally and anthropogenically in rural areas. Due to the high prevalence of drought and use of *tavy* around Sainte Luce, it is urgently important to understand the link between fire and the sustainability of *mahampy* weaving as a livelihood, in particular which of the harvesting techniques are most sustainable after a fire event, and whether any management mitigation needs to be taken.

[1] *Tavy* is a swidden agricultural practice, which involves setting intentional fires to clear land for agriculture.

The data collection in this Update Report was undertaken as part of Project Mahampy, which aims to improve the livelihoods of rural women in Madagascar through the Mahampy Weavers' Cooperative whilst ensuring that the reedbeds upon which they rely are healthy, resilient and productive. This report reviews the results from studies into the effect of harvesting technique on *mahampy* regrowth, and the effect of harvesting technique on *mahampy* regrowth after fire events. This report will also provide an update on *mahampy* reedbed health as estimated by Green Chromatic Coordinates from Drone Imagery.

2 Methodology

Project Mahampy conducts research across six wetlands in the Anosy region of southeast Madagascar (24° 46' S, 47° 10' E) (Figure 1).

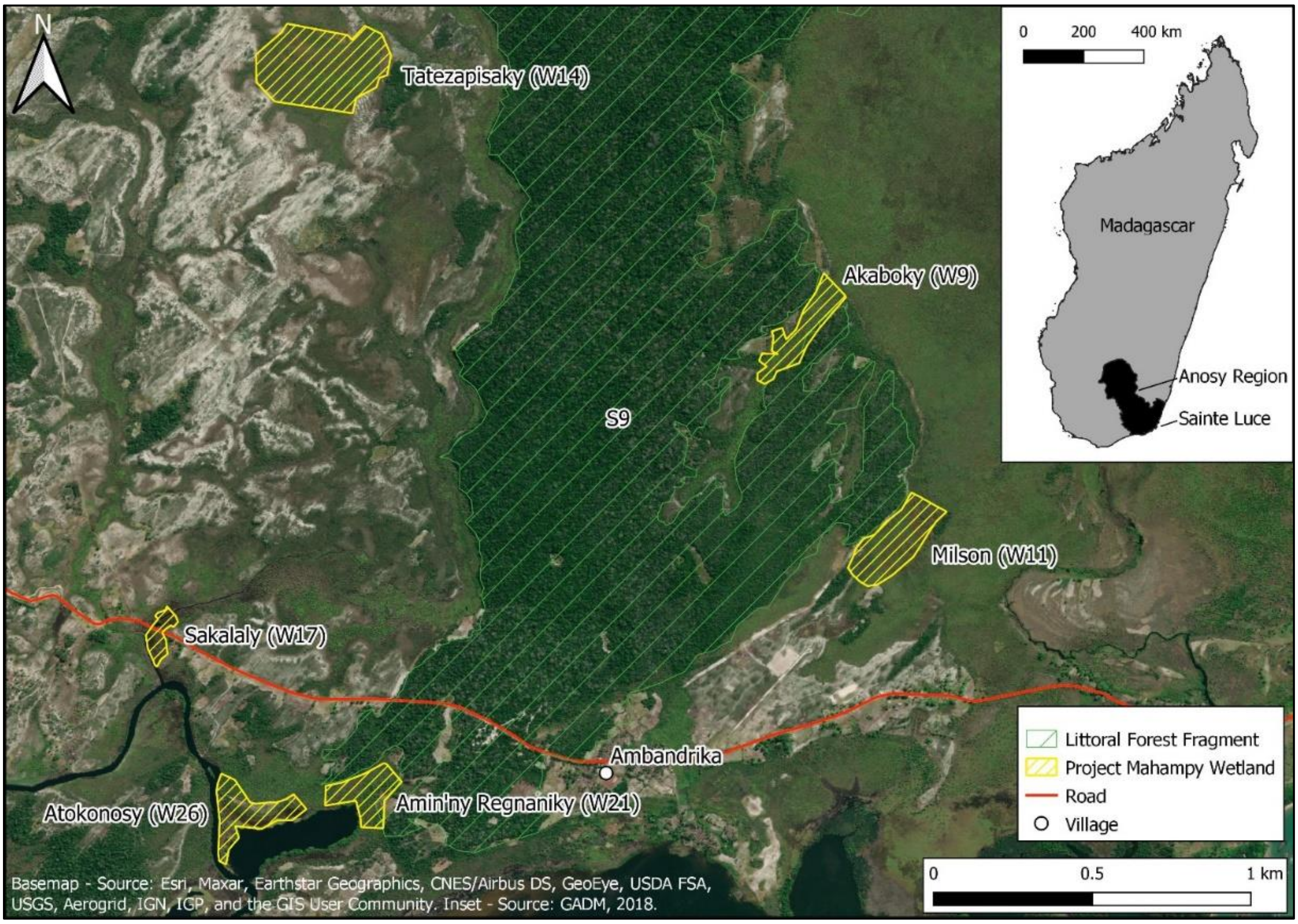

Figure 1: Sainte Luce study site.

Participatory Monitoring

To investigate the effects of harvesting techniques and fire on *mahampy* reedbeds, a participatory monitoring programme was set up and led by the Mahampy Weavers' Cooperative of Sainte Luce, who were particularly interested in determining whether the harvesting techniques used were detrimental to reedbed growth. This programme was then supported by staff from SEED's Conservation and Research Programme (SCRP). Such participatory monitoring programmes not only respond directly to the research areas identified as most pressing by resource users, but they are especially appropriate in wetlands as the health of the environment directly relates to the participants' livelihood (Andrianandrasana et al., 2005).

Harvesting Technique

To investigate the effects of harvesting techniques on the *mahampy* wetlands, Project Mahampy compared the condition and rate of regrowth of reedbed quadrats that were harvested using different techniques; either cutting or pulling.

Nine 2m x 2m quadrats were set up across three of the project's target wetlands (W9, W11 and W21). The *mahampy* in each quadrat was subjected to one of three treatments, harvested by the traditional local pulling method, harvested by cutting reeds near the base of the stem, or left unharvested. Each treatment (Pull, Cut or Unharvested) was applied to a quadrat in each wetland. All members of the Mahampy Weavers' Cooperative were informed of the research and avoided further harvesting by any technique within the quadrats. Poles with flagging tape were erected around each quadrat to reduce entry by other weavers or resource users.

Two months after the harvesting treatment was given, 25 of the regrown reeds were selected and labelled in each quadrat, and the height, diameter and condition were recorded. Data collection started in November 2022 and was conducted every other month thereafter. Condition was scored on a scale of 0-4 (Table 1). It was also recorded when a reed was *Gone*, accounting for specific reed mortality and that the entire stem and root was lost. Reed density was also measured by counting the number of alive *mahampy* stems in four 50cm x 50cm sub-quadrats within each of the four corners of the quadrat, and calculating an average.

Table 1: Description of the condition scores used to investigate the effect of harvesting technique on mahampy.

Condition	Description
0 – Dead	*Mahampy* is discoloured/dry/brittle.
1 – Very Poor	*Mahampy* is a pale colour throughout the reed with little root/growth.
2 – Poor	*Mahampy* is a pale colour throughout most of the reed and is inflexible.
3 – Fair	*Mahampy* is pale green or green throughout most of the reed and is flexible.
4 – Good	*Mahampy* is green and very flexible and may have evidence of flowering.

Fire

To investigate the effects of harvesting techniques on the *mahampy* wetlands after a fire event, Project Mahampy compared the condition and rate of regrowth of reedbed areas in W17 and W26 that were burnt in a natural fire in November 2021. Quadrats within these wetlands had previously been set up to investigate the effect of harvesting technique in the same way as wetlands W9, W11 and W21.

To determine the rate of regrowth of reeds within each quadrat, the diameter and height of 10 randomly selected *mahampy* reeds were recorded, before taking an average for the quadrat. The ten recorded reeds were randomly reselected at the beginning of each data collection session.

The overall coverage, condition and density of *mahampy* within each quadrat was also recorded. Coverage was measured by determining whether "all", "most", "some", or "none" of the quadrat was covered by *mahampy*. Condition was scored differently than when investigating the effect of harvesting technique, and was scored on a scale of 1-4, (Table 2). Reed density was measured by counting the number of live *mahampy* stems within four 50cm x 50cm sub-quadrats within each of the four corners of the main research quadrat using the same method as when investigating the effect of harvesting technique on quadrats not burnt by fire.

Table 2: Description of the condition scores used to investigate the effect of harvesting technique on mahampy *after a fire*.

Condition	Description
0 – Dead	*Mahampy* is discoloured/dry/brittle.
2 – Poor	*Mahampy* is a pale colour throughout most of the reed and is inflexible.
3 – Fair	*Mahampy* is pale green or green throughout most of the reed and is flexible.
4 – Good	*Mahampy* is green and very flexible and may have evidence of flowering.

Drone Imagery

To gain an understanding of Sainte Luce's *mahampy* wetlands on a larger spatial scale, Project Mahampy collected aerial imagery of the six target wetlands between August 2020 and July 2023 using a remotely piloted aircraft (Mavic Air DJI drone).

Each of the six wetlands were sampled approximately every four to six months to account for changes in the wetlands due to seasonality and time of year. The drone was flown on days without high cloud cover, rain, or high wind to minimise atmospheric effects on the imagery collected and reduce noise in each of the images. During data acquisition, the drone was flown at an elevation of 100m, moving at a speed of 10 meters per second. High resolution true colour (RGB) photographs (4056 x 3040 pixel resolution) were taken every 10 meters. The drone's camera lens was angled perpendicular to the ground throughout the flight to minimise image distortion. To ensure full coverage of each wetland (as predefined by spatial polygons identified from satellite imagery), digital flight paths were programmed and stored in Litchi (flylitchi.com). The collected photographs were stitched together in Structure from Motion (SfM) software using the GPS data embedded in each photograph. To achieve this, OpenDroneMap (opendronemap.org) was used to produce a single GeoTIFF file to be analysed in a Geographic Information System (GIS). Due to limited on-the-ground staff capacity, ground truth data were unable to be collected.

Quantum GIS (QGIS) was used to analyse aerial imagery and create maps of each wetland. Green Chromaticity Coordinates (GCC) is an index that uses bands only in the visible spectrum (i.e. red, green, and blue), and used as a proxy measurement for health wetland vegetation. A higher GCC is indicative of a healthier wetland, with a higher index indicating a greener wetland, and a greener wetland being healthier (Schneider et al., 2008). All analyses of the imagery took place in QGIS, with each true colour image being separated by red (620-750 nm), green (495-570 nm), and blue (450-495 nm) wavelength first, and indices then calculated using the following equation (Figure 2).

$$GCC = \frac{green}{(green + red + blue)}$$

Figure 2: Equation used to calculate the Green Chromaticity Coordinate; the colours refer to the colour band created from the true images.

GCC is an index that is not as affected by varying sampling conditions such as sunlight brightness and angle, and camera properties, as other indices (Larrinaga and Brotons, 2019). This is important as the drone flights took place at different times of the day and year. Differences in GCC between wetlands were confirmed statistically using an Analysis of Variance (ANOVA) test conducted in R (R Core Team, 2021).

3 Results

Participatory Monitoring

Harvesting Technique

Between October 2022 and August 2023, each of the three study wetlands were visited six times to determine how harvesting technique affects *mahampy* growth. By August 2023, the highest average *mahampy* height was found in the Pull quadrats (Table 3), however there was no significant difference in the proportion of reeds recorded as *Gone* (assumed mortality) between the Pull and Cut harvesting techniques (Generalised Linear Model: $p = .0763$). Quadrats harvested using the Cut harvesting technique had a significantly higher average reed density than the Pull harvesting technique (Generalised Linear Model: $p < .02 \times 10^{-14}$). Figure 3 shows how the average height of *mahampy* reeds changed over time for each of the different treatments. Figure 3 suggests that for both the Unharvested and Cut reeds there is a decline in average reed height over time, whereas the average height of reeds in the Pull quadrats show an initial increase in average height before declining.

Table 3: Descriptive statistics for each of the harvesting techniques from the most recent period of data collection, August 2023. All descriptive statistics include the reeds that were Gone*, aside from the most frequent reed condition (mode) which refers to the condition of reeds that were not* Gone.

Harvesting Technique	Mean Reed Height (cm)	Median Reed Height (cm)	Range of Reed Heights (cm)	Most Frequent Reed Condition	Proportion of Reeds Gone	Average Reed Density (reeds/1m^2)
Unharvested	7.84	0.00	97.00	4	66/75	315.33
Cut	1.07	0.00	80.00	4	74/75	355.33
Pull	23.47	0.00	120.00	4	50/75	205.00

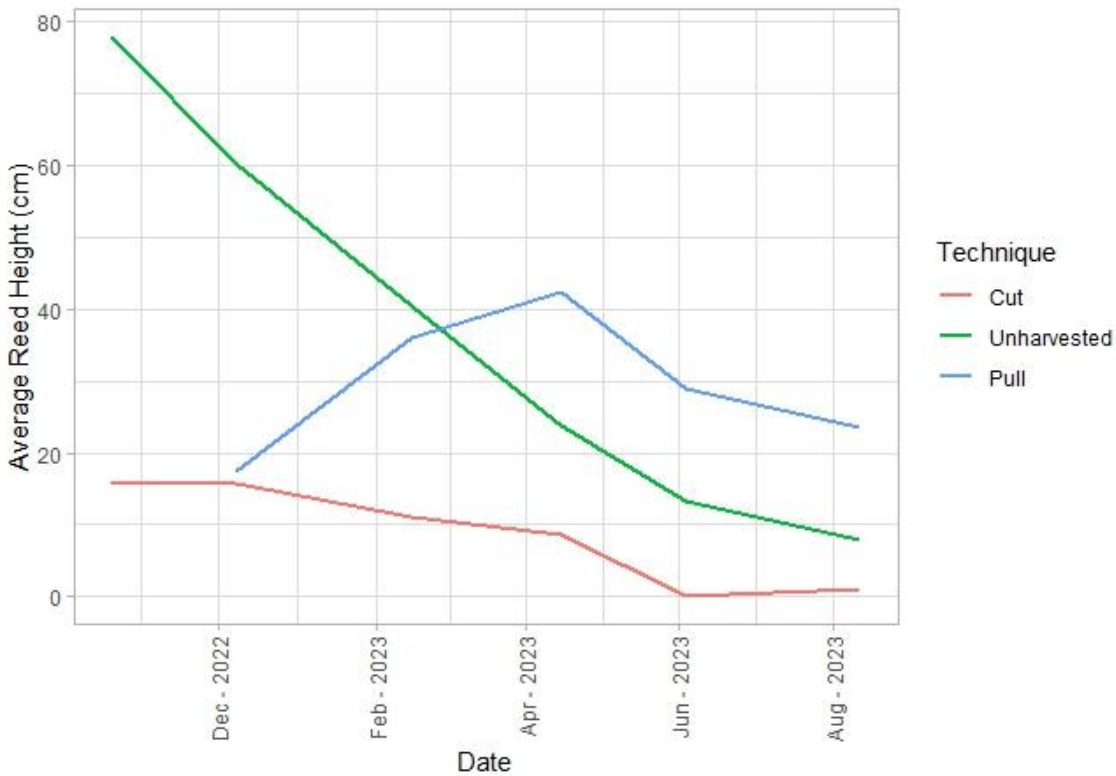

Figure 3: Graph of the mean mahampy *reed height over time for each of the harvesting techniques.*

Reed height in August 2023 was not normally distributed (Shapiro-Wilk test: $W = 0.45575$, $p < .022 \times 10^{-14}$), therefore a Kruskal-Wallis test was run. This indicated a statistically significant difference in the height of *mahampy* reeds between harvesting techniques ($\chi^2 = 29.855$, $df = 2$, $p = .03289 \times 10^{-5}$). Using Dunn's Test for Multiple Comparisons it was found that the reeds harvested using the Pull technique were statistically taller than both the Cut (difference = 5.36, $p = .0252 \times 10^{-5}$) and Unharvested (difference = 3.61, $p = .0624 \times 10^{-2}$) reeds at the most recent data collection session, in August 2023 (Table 4).

Table 4: Summary statistics using Dunn's Test for Multiple Comparisons for the differences in height of mahampy *reeds with different harvesting techniques from the most recent period of data collection, August 2023.*

Comparisons	Difference	Adjusted p-value	Statistically Significant
Cut-Unharvested	1.75	0.0796	No
Cut-Pull	5.36	0.0252×10^{-5}	Yes
Unharvested-Pull	3.61	0.0624×10^{-2}	Yes

Fire

Between November 2021 and July 2023 each of the two study wetlands was visited 11 times to investigate the effects of harvesting techniques on mahampy reed regrowth after the reeds were burnt by a fire in November 2021. Figure 4 shows how the mean *mahampy* reed height fluctuated over time for the Pull, Cut, and Unharvested reedbeds. During the most recent monitoring session, in July 2023, it was found that the average reed density was significantly higher for reeds in the Pull quadrats than Cut quadrats (Generalised Linear Model: $p < .02 \times 10^{-14}$) (Table 5).

Table 5: Descriptive statistics for each of the harvesting techniques from the most recent period of data collection, July 2023.

Harvesting Technique	Mean Reed Height (cm)	Median Reed Height (cm)	Range of Reed Heights (cm)	Average Reed Condition	Average Reed Density (reeds/1m^2)
Unharvested	77.80	80.00	68.00	3.5	441.50
Cut	76.25	75.00	150.00	2.5	326.00
Pull	73.50	75.00	80.00	3	509.00

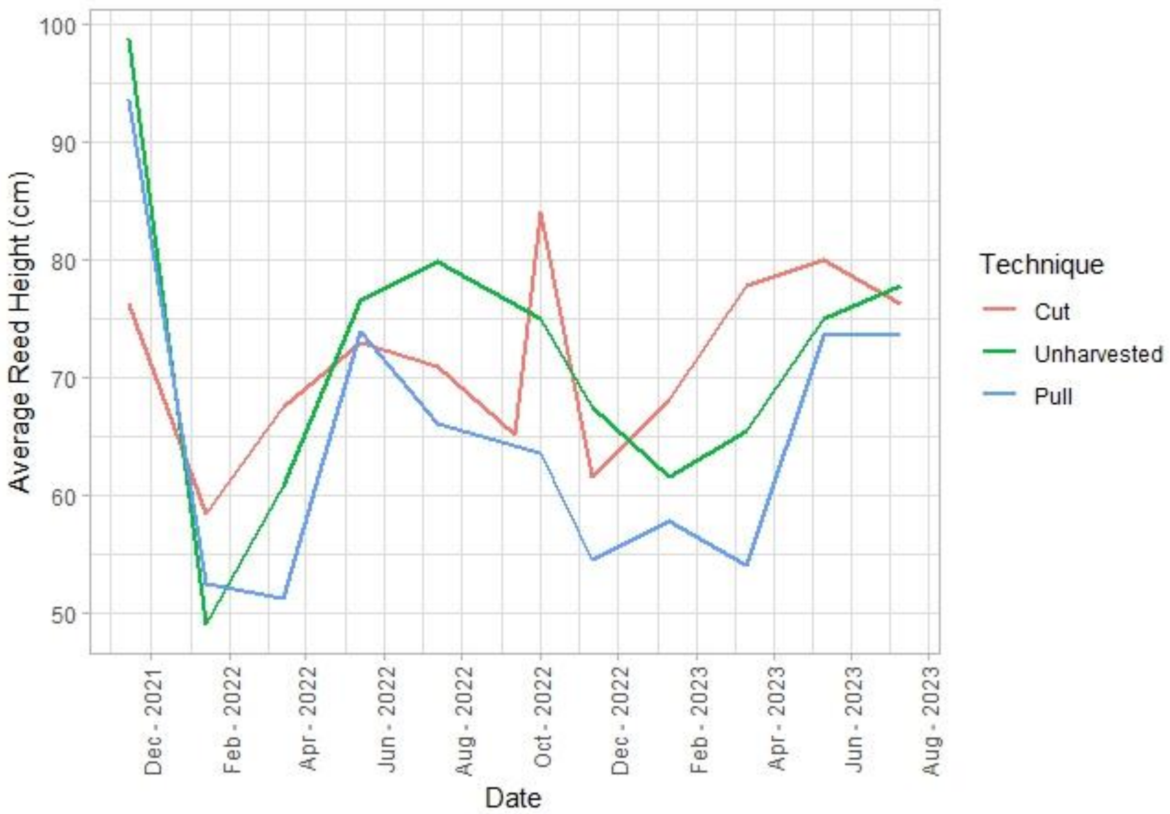

Figure 4: Graph of the mean mahampy *reed height for each of the harvesting techniques after the reeds were burnt during a fire in November 2021.*

Reed height at the most recent data collection session, in July 2023, was not normally distributed (Shapiro-Wilk test: W = 0.94527, p = .009384), therefore a Kruskal-Wallis test was run, indicating there was no significant difference in reed height between the harvesting techniques (χ^2 = 0.28892, df = 2, p = .8655).

Drone Imagery

Between August 2020 and July 2023, a total of 47 aerial surveys took place, four times a year. Due to adverse weather conditions and technical difficulties, an aerial survey of Wetland 26 in August 2020 was not possible. There were no planned aerial surveys conducted between November 2021 and October 2022, meaning that the effect of fire in W17 and W26 on GCC was not recorded.

High resolution true colour images of each of the project's study wetlands from July 2023 are shown in Figure 5, whilst Figure 6 shows the mean Green Chromatic Coordinate (GCC) for each wetland over time. In most of the wetlands, mean GCC values showed little variation through time (Figure 7). Wetland 21 presents the highest mean GCC value across the time period (0.39), whereas Wetland 17 presents the lowest mean GCC value (0.34).

Mean GCC values were normally distributed (Shapiro-Wilk Test: W = 0.97, p = .17) and so an ANOVA was used to compare differences between the wetlands. There is a significant difference in mean GCC values between wetlands (ANOVA, df = 5, F = 44.20, p = $.0184 \times 10^{-13}$) with Wetland 21 having a higher mean GCC than all other wetlands and W17 having a lower mean GCC than all other wetlands (Post-hoc comparisons using the Tukey test; p < .05, Annex 1).

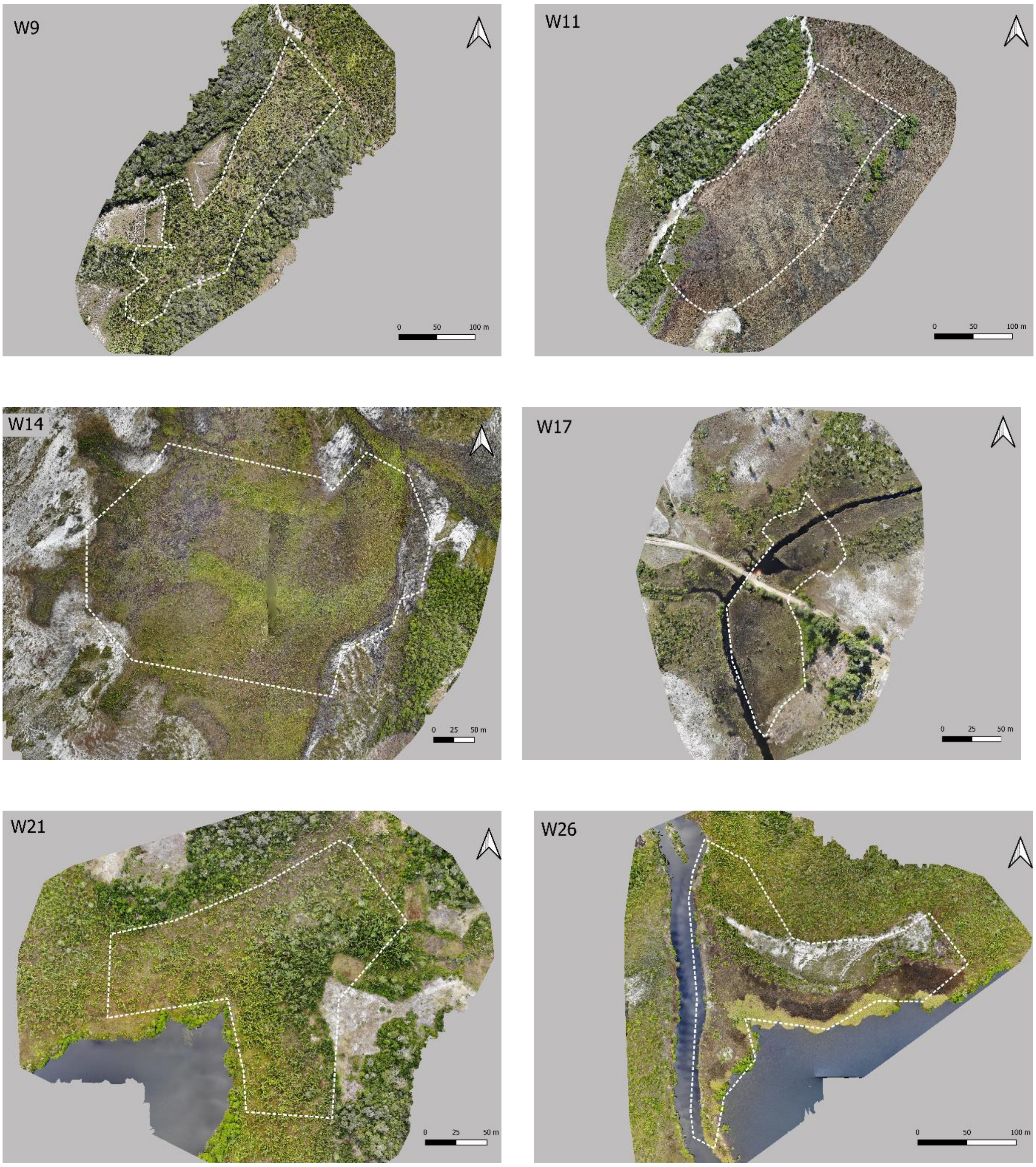

Figure 5: Panel of aerial images of all of Project Mahampy study sites collected in July 2023. The boundary of each wetland is highlighted with a white dotted line.

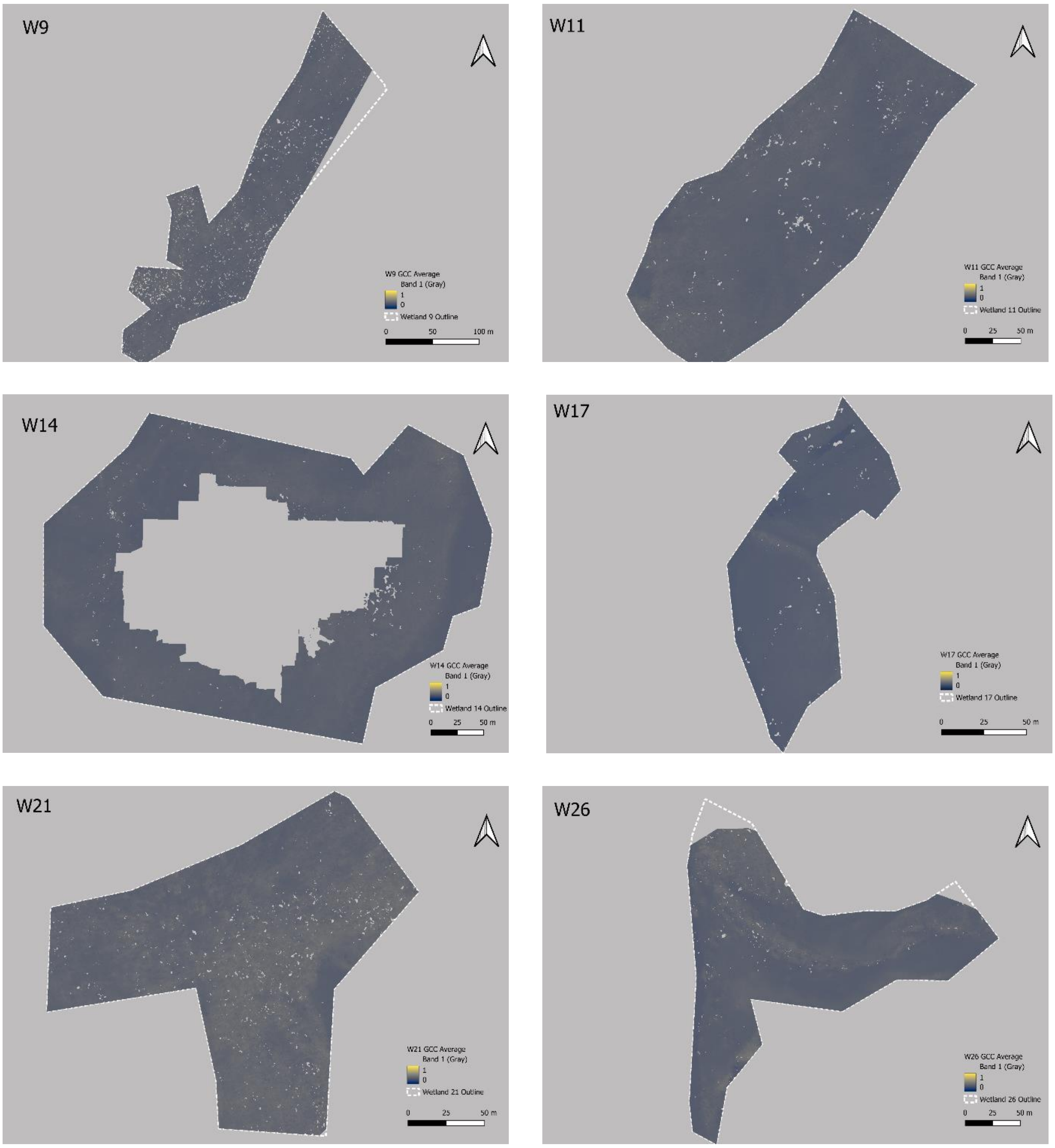

Figure 6: Panel of the temporal Average Green Chromatic Coordinate (GCC) for each of the Mahampy Project's wetlands, from August 2020 to July 2023.

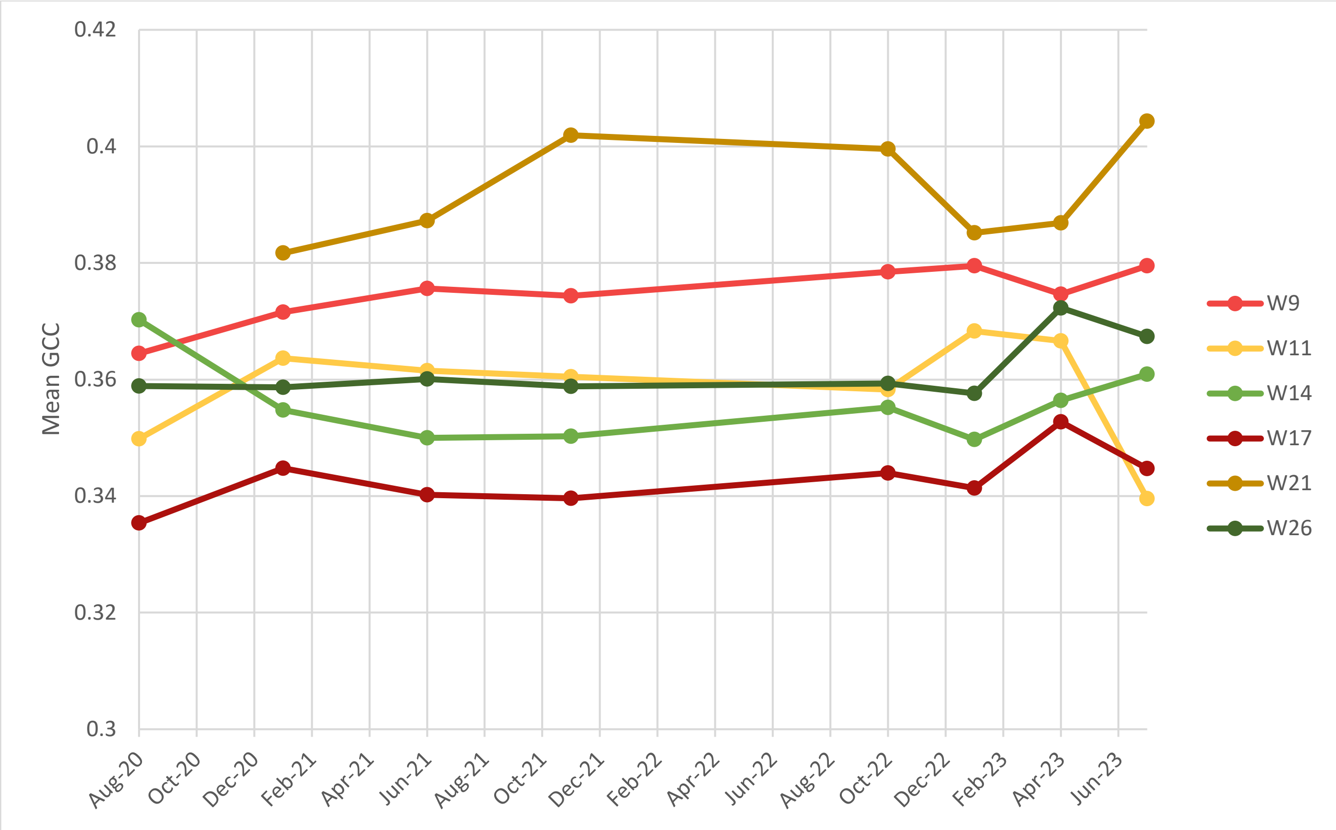

Figure 7: Graph showing how the GCC for each of the Mahampy Project's wetlands changed over time.

4 Conclusions

Investigating the effects of harvesting techniques on *mahampy* reed growth for Project Mahampy aims to inform the sustainable use of resources for future use. Data collection in W9, W11 and W21 for investigating the effects of harvesting techniques shows that the Pulling technique generates the best regrowth throughout the period of data collection. After 10 months it was also found that Pull quadrat reeds were statistically the tallest of the three treatments. This indicates that the Pulling technique would be the most sustainable.

Data collection in W17 and W26 to investigate the effect of harvesting technique on *mahampy* regrowth after a fire event indicates that when there is a fire after m*ahampy* reeds have been harvested, there is no difference in regrowth between the different harvesting techniques. The observed fluctuations in reed height over time seem to follow changes in the seasons, where average *mahampy* reed height decreases during the dry season and then increases after a period of rain. Despite no statistically significant differences in mean *mahampy* reed height between harvesting techniques, the Pull quadrats show a higher mean reed density than the Cut quadrats. Additionally, reeds in the Pull quadrats anecdotally had higher condition scores than in Cut fragments. This could suggest that the pulling technique would be more sustainable for harvesting in wetlands impacted by fire.

Wetland health, calculated using the GCC, shows little variation over time, although some cumulative differences between wetlands can be seen. W21 shows the highest mean GCC, while W14 and W17 shows the lowest. These differences could be influenced by the distance from the river and the effect of fire on wetland health. However, the direct effect of fire on wetland health after the fires in W17 and W26 in November 2021 was undetected in the change in GCC as there were no aerial surveys between November 2021 and October 2022.

5 References

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6 Annex

Annex 1 – Summary of differences in wetland GCC values derived from one-way ANOVA and Tukey test analyses.

Wetland	Difference	p-value (adjusted)	Statistically Significant
W14-W11	-0.002595346	0.9760003	No
W17-W11	-0.015689585	0.0008403	Yes
W21-W11	0.033861146	0.0000000	Yes
W26-W11	0.003108073	0.9484573	No
W9-W11	0.016227431	0.0005252	Yes
W17-W14	-0.013094239	0.0073579	Yes
W21-W14	0.036456492	0.0000000	Yes
W26-W14	0.005703419	0.5902183	No
W9-W14	0.018822777	0.0000511	Yes
W21-W17	0.049550730	0.0000000	Yes
W26-W17	0.018797658	0.0000523	Yes
W9-W17	0.031917016	0.0000000	Yes
W26-W21	-0.030753073	0.0000000	Yes
W9-W21	-0.017633715	0.0002567	Yes
W9-W26	0.013119358	0.0072119	Yes