Where does the Parkietenbos landfill end? A waste and pH-gradient assessment

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"Two completely different worlds"

I pull out another bag. "Oh look", I say unsurprisingly but with a heavy heart. Under the dirt is yet another bag, just below the plastic bag I had pulled from the ground just a second before. Thinking I would have completed the transect plot quickly, I look up, dumbfounded by the realization that I had still only just begun – there were scraps of plastic sticking out everywhere, camouflaged by leaves, and the dust and ash that drops from the sky.

I've been working in the forest - downwind of the landfill - for 7 hours now, unable to take a clean breath all that time. I wear my facemask and pray the filters don't run out – the air around me is thick with the stench of smoldering toxins, and I can hardly see 10 meters in front of me. Why am I reciting my day to myself as though it is a book? Honestly I wonder how useful this facemask is in these conditions, I still feel as though I am oxygen depleted.

My experience around my research had many faces, but the actual field research was oft heart breaking. It baffles me how we can speak so positively of ourselves yet be so careless. On LinkedIn, Serlimar Sui Generes states that their operation provides the Aruban community with a *"clean and healthy environment by ensuring a responsible, service oriented and efficient implementation of activities relating to waste prevention, collection and processing and green space."* The Parkietenbos Landfill and Container Park, operated by Serlimar Sui Generes – the government entity in charge of waste disposal on Aruba – supposedly has official boundaries, yet my research and experience can show that these boundaries are but another situation where we decide to turn a blind eye. We claim many things, but the brutal truth is not nearly enough has been – or is being – done to make a difference, nor are we willing to take responsibility for our faults.

Although my research was often very heavy, my overall experience in Aruba and of this project has been uplifting. The collaboration effort between the University of Aruba and University College Utrecht has been extremely successful; friends were made and amazing experiences were shared. Something I found truly inspiring was how quickly those involved were willing to help each other with difficulties they faced; whether it was to get their own hands dirty or to provide contacts of those who could be more helpful. It is because of the people involved in the project that I also know that the first steps are being made to try to live up to the Aruban vision. It may be a difficult road, but clearly there are some that care, and are trying to find different ways of dealing with the environmental issues present on the island.

What an experience it has been, and never will I look back with regret. My research has left me stunned; however, the beauty and kindness of Aruba and her inhabitants has left me stunned all the same. I truly experienced Aruba as two completely different worlds, and it has been beautiful.

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1. Introduction

A healthy environment is quintessential for any type of floral growth; of course this includes certain consistent (and specific) conditions, such as healthy pH levels. pH is affected by a variety of different things, typically chemically related such as industrial effluents or runoff from power plants, but can also be affected by temperature and disruption of soils (oxidation of otherwise oxygen depleted soils; EPA). Another key factor for healthy environments is maintaining an *undisturbed* system. Trash and debris of all sizes disturb the ecosystems in various ways, and in mangrove ecosystems trash is just as destructive. Large debris can hinder the growth of trees and damage the roots. But smaller, lighter and seemingly harmless trash can be just as – if not more – destructive. Plastic bags for example can get tangled in the prop roots and suffocate the trees or create anoxic conditions (DG Environment News Alert Service, 2011). These are well-established facts, however, in Aruba there is little information or data on the mangrove ecosystems. Very clear though is that the mangrove ecosystems in Aruba are highly disturbed, particularly surrounding the Parkietenbos Landfill and Container Park and are subject to immense amounts of trash annually.

1.1 Mangroves' importance

Mangroves provide a list of services both ecological and anthropogenic, ranging from breeding grounds for fish and supporting the fishing industries to coastal and coral protection, sediment retention and coastal substrate stabilization (Anthony and Gratiot, 2012). Whilst the list continues, some of the most important functions of mangrove ecosystems for Aruba are the protection they provide against storm surges, coastal erosion and sediment retention, their filtration services (photosynthetic, gaseous, and within the surface soils and waters), their provision of breeding, resting and hiding grounds for fish and crustaceans; the protection they provide the coral reefs and of course their aesthetic qualities for the tourism industry.

Parkietenbos in particular should be an area of concern, not only because of its increasingly deteriorated state, but also because it is one of the largest remaining mangrove areas on Aruba, and one of the first and last things one sees when arriving and departing from Aruba. For the tourism industry – which Aruba is heavily dependent on – it should be a priority to maintain a clean, green environment, as this is also one of Aruba's main advertisements. Parkietenbos acts as a shield for the Parkietenbos Landfill and Container Park as it not only hides the view of the landfill from certain angles from boaters, but also contains a lot of the waste which is carried away from the landfill due to the coastal winds and currents along the area – predominantly (but not limited to) plastics, which would otherwise likely end up in the bay of Oranjestad or on the beaches along the tourist stip.

Unfortunately, the Landfill and Container Park has expanded to approximately 18ha and currently reaches a height of 42m, and is now seen towering over the mangroves of Parkietenbos. The boundaries of the landfill are becoming increasingly difficult to understand, as the landfill is slowly expanding towards sea, and further into the mangroves, largely because of improper waste disposal. Furthermore, due to the constant open-air, uncontrolled burning of materials on the landfill, smoke clouds cover the forests regularly (see cover photo). Usually however, the landfill is smoldering, thus not noticed as much unless in the area, yet white smoke travels across the forest and water towards the southern barrier reef.

1.2 Research

This research examines whether there are still clear boundaries of the landfill and if the waste is actually contained. In doing so, this research investigates the pH-gradient of the forestry on both sides of the landfill to assess the possibility of acidic leaching and other underground processes from the landfill, and will also investigate the trash concentrations found within the forests. The trash analysis will provide an indication of the current physical conditions and provides an inventory of the types of solid wastes that can be found, from which we can argue whether they are predominantly originating from the landfill directly, or if they originate from illegal disposal and littering. Furthermore, this research will investigate if the growth of the mangrove forests of Parekietenbos is stunted due to, potentially, pH-levels and trash concentrations. This particular paper however, will only review the preliminary findings on the pH-gradient and the trash concentrations. The research questions thus are as follows:

1. Does the Parkietenbos Landfill and Container Park have and maintain its boundaries?

2. How does the Parkietenbos Landfill and Container Park negatively affect its surrounding forestry with regards to improper waste disposal and the pH gradient?

1.3 Hypotheses

We expect that the pH of the Left and Right Parkietenbos will be significantly lower than that of the Spanish Lagoon, suggesting that not only are the areas under the healthy norm for Aruba, but are also significantly more acidic due to the proximity of the Landfill and Container Park.

We expect to see that the Left parkietenbos is significantly more affected by wastes – especially soft plastics (predominantly bags, fragments and foam) as they are often carried downwind, and are then caught in the trees or in the roots.

2. Methodology

2.1 Equipment

This research utilized a thermometer, Garmin eTrex 10 GPS, Google Earth Pro, compass, two Luster Leaf Rapitests (Digital Soil pH Meter), Universalindikator Merck, distilled water, (max. 40kg, min .01kg), 3m Stanley measuring tape, string, a Samsonite weight scale, and the NOAA Data Sheet for Field Surveys. For safety puposes a filter facemask was worn throughout the duration of each survey of the Left Parkietenbos as the area is downwind of the landfill.

2.2 Study Area

This research focused solely on the mangrove forestry on either side of the Parkietenbos Landfill and Container Park; however, did use the Spanish Lagoon for baseline information on the pH-gradient, trash densities and composition, and tree sizes. For the purpose of this research, the study areas are known as *Left Parkietenbos*, *Right Parkietenbos*, and the *Spanish Lagoon*.

Image 1 illustrating the focal study area of this research.

2.3 Procedure

Ultimately, two methods for conducting the research were used; the first method was initially proposed for both the Left and Right Parkietenbos; however, was ultimately only used for the Left Parkietenbos and for one (the only) transect in the Right Parkietenbos; and the second method was used for the Spanish Lagoon (as the measurements here are baseline and not based on distace from the landfill) but was ultimately also used for the majority of the Right Parkietenbos due to the circumstances of that particular area.

2.3.1 Left Parkietenbos

The researcher(s) walked along a 'horizontal' *transect* (perpendicular to the landfill boundary), *ideally* every 50m along the width of the Left Parkietenbos, starting at meter 0(transect 1) (top right of the Left Parkietenbos), followed by a transect (2) starting at meter 50, 100(transect 3), …, 250(transect 6). A few things were considered however; firstly, in keeping with the ultimate goals of this research it was essential to sustain the least possible amount of damage to the area and its inhabitants, which resulted in slight detours at times and the losing of some bearings; secondly, some of the transects (3 and 5) were conducted in alternating directions to avoid systematic variance of the pH-gradient of the system because of the influence of temperature, which meant that for these transects the starting point was loosely based on what was expected to have been the end of the horizontal line (transect) starting from their respective starting positions (meters 100 and 200). With this in mind, the researcher used a compass and tried to hold a bearing of 302° when heading towards the waterfront (away from the landfill), and when conducting transects with an alternative direction a bearing of 122° was maintained. We used a GPS to mark our initial and final locations to better visualize the transects. Each transect continued until a significant change in the local system occurred; for example, where the ground substrate became predominantly water (transects 1,2,4,6), the landfill (transects 3,5) or a beach (transect 1; Right Parkietenbos).

Along each transect two pH measurements were made every 2m, one with each Luster Leaf Rapitest. A second handheld digital reader was used throughout the surveys to act as a control mechanism, provide more data and to save time. The digital readers were always positioned approximately 50cm apart.

Furthermore, a series of *plots* were created every 20m. A plot is an area of 4x4m where all trees were counted according to their productivity (if a tree had leaves it was considered productive), the tree circumferences measured and all trash was collected, sorted, weighed and recorded. The trash is collected only after the pH levels have been recorded at all 3 points (meter 0, 2, 4) of the plot since the removal of the wastes could cause oxidation processes to occur, thus changing the pH of the local environment. As the plots are 4x4m, the plots occur at meters 0, 24, 48, 72, etc. until the end of the transect.

2.3.2 Right Parkietenbos and the Spanish Lagoon

The first method was applied to the only transect in the Right Parkietenbos, starting at the bottom left corner of the area. However, due to the surface and ground consistency of the area the pH measurements are limited to only certain areas to avoid damaging the Luster Leaf Rapitests. For the remainder of the study area and that of the Spanish Lagoon this research applied the second method.

The second method consisted of completing all requirements at each plot, whenever possible, or rather, whenever space and access permitted it. The Right Parkietenbos is largely an overwash forest (Hutchings & Saenger, 1987), making the area largely inaccessible, limiting the plots to or near the borders of the study area.

The Spanish Lagoon is used for baseline information, and due to its more positive characteristics; is associated as the healthy norm for Aruba. For the Spanish Lagoon the plots were also limited to the outskirts of the lagoon, mainly on the left side and end of the lagoon. The plots were limited to areas where spaces in the mangle growth allowed the researcher to venture away from the walking trails, to get more representative data. The area of Spanish Lagoon on the water directly connected to the Caribbean Sea, is seemingly a pristine and undisturbed area, showing signs of epibiont sponge growth (a positive indicator of mangrove health; Diaz, Smith and Klaus, 2004) and has a thick concentration of *rhizophora mangle (red mangrove)*. This, however, meant that there were only a handful of pockets where data could be gathered whilst keeping the area mostly undisturbed. The end of the lagoon, being much more open, allowed many plots to be made; however, it is important to make the distinction as this area is no longer directly accessible by water from the lagoon.

3. Results

3.1 Area description

The smoke is thick and the scent of burning chemicals is strong. The Left Parkietenbos, being downwind of the landfill, clearly suffers more from the effects of improper waste disposal. The wind carries plastic wastes through the air and disposes it like sediments in the trees. The trees within 30-50m of the landfill suffer substantially more. The productivity tree count suggests that there is significantly less new growth within this area, especially within the first quadrants. The trees that have survived thus far are decorated with plastic bags, and the leaves still present on the trees are filled holes and covered in dust and ash. The ground is more covered with trash than it is uncovered, only sometimes seems lesser than is actually the case because the trash is camouflaged by the leaves, ash and dust that have also fallen from the sky. The only colors seen are those from new solid waste that has recently drifted into the system. Everything else is eerily gray and quiet, as this area of the forest is largely uninhabited, other than the flies and the odd passerby bird or dog. The abundance of trash could elucidate the increased number of unproductive trees, the lack of new growth. The transformation of the forest with increasing distance from the landfill truly is astonishing.

Surprisingly, the red mangroves, when present, are clearly better adapted to dealing with the conditions. The red mangrove seems to have less difficulties growing, the majority of the Left Parkietenbos seedlings and saplings are red mangroves and their leaves are far less damaged than those of the white and black mangroves. Whilst white mangroves also occur in the area, the trees are showing much greater signs of stress in the area, as the vast majority of the white mangroves in the Left Parkietenbos have heavily affected leaves, and there are almost no seedlings and/or saplings to be found.

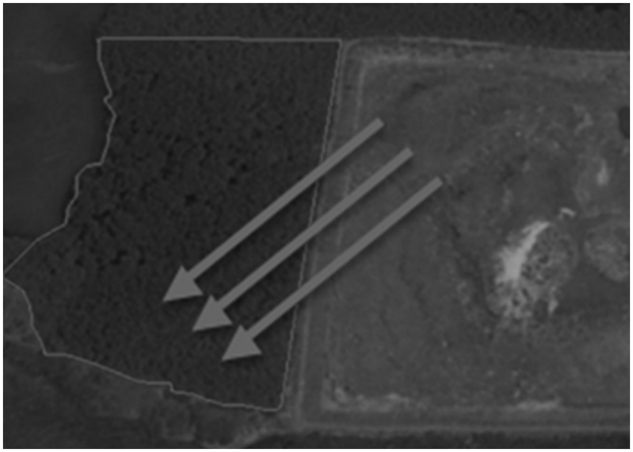

Image 2. Image illustrating the general direction of the coastal winds in Aruba along the Landfill & Container Park.

As illustrated by Image 2, the bottom right corner of the Left Parkietenbos is the most affected area. Unfortunately, the area was much worse than expected, with the ground being trapped under more than 50cm of plastic build up.

3.1.1 Transect 6; Left Parkietenbos

During cleanup of the first plot of the final transect (6; at meter 250) with every bag that was collected, another one would turn up beneath it. The bags had piled up and tree roots had tried extensively to grow through the plastics. An often seen image, sadly, is that of a plastic bag raised like a tent, because a root was trapped under it, slowly suffocating. This *one 4x4 m quadrant*, contained 137.57kg of waste, and took more than 4 hours to clean up. In total – for this quadrant alone – we collected 2731 individual items, of which 93.37% (2659 items) was plastic. Of this total, 2402 items was plastic bagging (1830 plastic bags, 266 plastic bagging (thicker plastic) and 306 soft plastic fragments (fragments of single-use plastic bags)). Even after 4 hours on this plot, not all the waste was collected, as there were still fragments sticking out from the mud, and some bags could still be found in the treetops.

Although there was less trash to be found on the rest of transect 6, the concentrations of trash remained significantly higher when compared to earlier transects. It is likely that, due to the proximity of the transect to the border of the forest, there is more space surrounding the transect, allowing debris to enter the system more easily. However, more likely is that the wind factor plays a greater role in abundance of trash on the transect, as a greater portion of the transect is directly in the landfill plume.

3.2 pH-Gradients

3.2.1 Spanish Lagoon

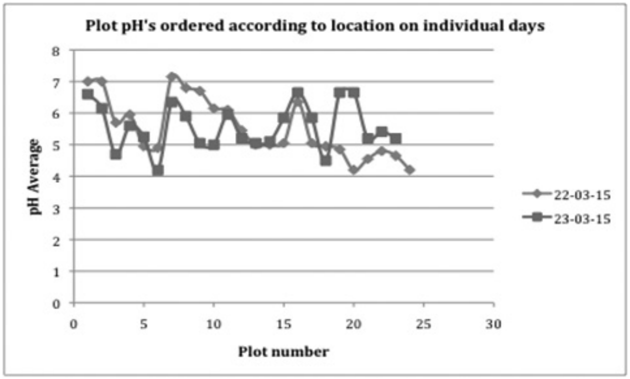

Figure 1. Graph showing the pH levels of each plot according to location on their respective survey days.

As figure one shows, the pH-levels of the system vary quite significantly. Please note, however, that plots 1-8, 10 and 13 from day 22-03-15 are the exact same plots 23-16, 12 and 10 respectively. There were two surveys completed at the Spanish Lagoon to account for systematic variance of the effects of temperature on the pH-gradient, and also to increase the amount of information available on the system. Thus, day 23-03-15 actually started with plot 23. Also, important to note is that the large variety in pH could be largely dependent on the distance from water in the lagoon. As an example, the pH-levels of plots 23, 22, 21, and 18 of 23-03-15 were found in much more barren locations, relatively far from water and more representative of a basin forest; whereas plots 20 and 19 were in close proximity to water, and contained *rhizophora mangle*.

3.2.2 Left Parkietenbos

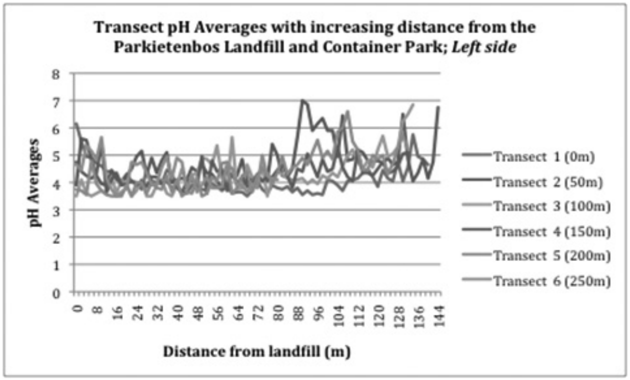

Figure 2. Graph showing the pH-gradients for transects 1-6 in the Left Parkietenbos.

Figure 2 shows the changing pH-gradients (based on the average of both measurements per site) changing with increasing distance from the landfill. Although it may not seem significant, there is a slightly positive correlation between pH-levels and distance from the landfill; and since pH is a negative logarithm (base 10) the difference in hydrogen ions between – for example – pH 5 and 6 is ten-fold. Thus, if we examine the graph above, the difference is actually a lot bigger.

Also, the Luster Leaf Rapitests have an acidic limit of pH 3.5 which was obtained on several occasions. Unfortunately, we did not have a method for successfully measuring the pH without influencing and disrupting the system so were limited to this restriction. Nevertheless, we can still observe a pH increase of approximately one complete level (pH 4 à pH 5). As alluded too in the *Area Description*, its incredibly how adaptive mangroves are and how well they can withstand the pressures exercised on them and the conditions of the area.

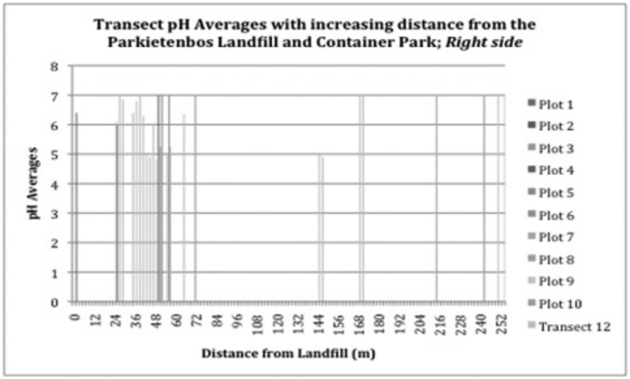

Figure 3. Graph showing the pH-gradient for the plots and transect of the Right Parkietenbos.

Figure 3 illustrates the variability of the pH-gradients for the Right Parkietenbos. Clearly seen is that the lowest reading found in the Right Parkietenbos was pH 4.8 – significantly higher than those found in the Left Parkietenbos. However, due to the substrate composition the results here are questionable, considering that there is a greater possibility that sands in the ground altered the pH measurements as they are more coarse particles that may carry a different pH than the soils. Furthermore, a lot of information is missing from this figure, as the measurements are limited predominantly to the borders of the forest, and only 3 measurements against the landfill border were made.

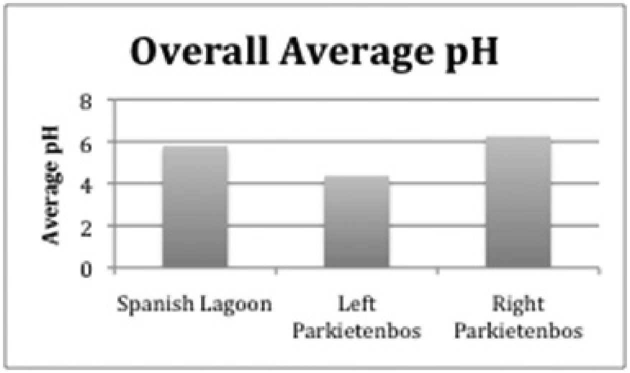

Figure 4. Graph illustrating the average pH-levels for the entire individual systems.

Inferable from the information provided by the transect, is that if more data is gathered from more variable locations within the study area – including more plots along the landfill and more centralized plots – potentially lower pH (more acidic) readings could be observed.

Interestingly though, is that the averages of the pH-gradients of each individual system shows that there are very clear differences between the individual study areas. Most surprisingly still, is the average pH for the Right Parkietenbos. However, as previously mentioned, there may be other factors influencing this outcome. Most important to notice from this outcome, is the very acidic average pH level for the Left Parkietenbos, supporting our initial hypotheses.

3.2 Trash concentrations and composition

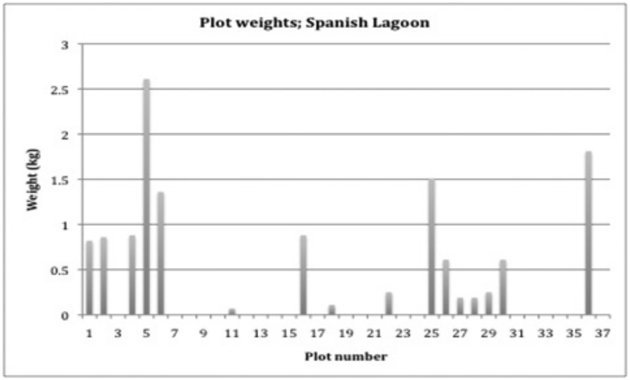

Figure 5. Graph showing the total weight of trash collected at each plot for the Spanish Lagoon. Recall that plots 1-8, 10 and 13 of 22-03-15 are the same plots as plots 23-16, 12 and 10 of 23-03-15 respectively, thus there are 37 plots listed, instead of the original 47. The plots listed from 25-37 are the plots from 23-03-15 that are unmatched in chronological order of how they were conducted.

Figure 5 illustrates the weight of the trash collected at different plots in the Spanish Lagoon for both survey days. Given that there is a no relationship with the landfill here, as the study areas are not neighboring one another, it is understandable that we do not see a specific pattern emerge.

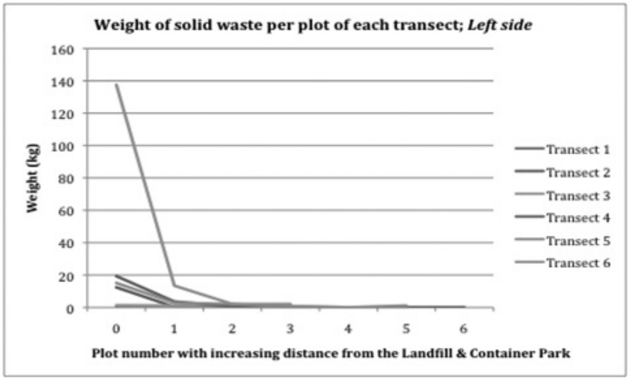

Figure 6. Graph showing the plot weights collected along the transects in the Left Parkietenbos.

As Figure 6 clearly shows, and not surprisingly, is that in the first plots – the plots closest to the landfill – the greatest volumes of waste were found. This graph also supports what was mentioned earlier regarding the wind patterns in the area, as transects 4, 5 and 6 all have the greatest amount of trash present in at least the first 2 plots. Furthermore, it shows how important mangroves are and how well they can prevent continued transportation of waste. This is important, because as mentioned before, all the waste blocked and contained by the trees would end up in the ocean if the Parkietenbos forestry was inexistent, and would further damage marine ecosystems, and more heavily impact the tourist industry on Aruba.

Given that transect 6 alone contained more than 2731 items; the amount of trash in the area and the effects thereof is unimaginable. It is crucial that such findings are used to further stimulate the political agenda by supporting environmental causes and policies such as the currently developing 'Plastic Bag Ban'. Hopefully, by compiling a plethora of evidence to show the negative impacts on our local environments, we can convince authorities to take further and more drastic measures to aid the regeneration of the local environments.

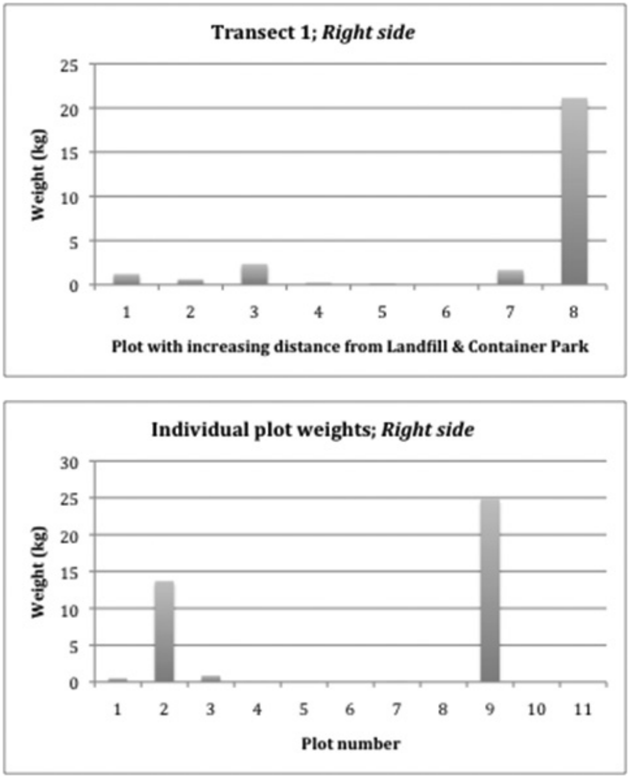

Figure 7. Graphs A and B showing the transect and plot weights of the Right Parkietenbos respectively.

Similar to the Spanish Lagoon, no direct correlation between trash concentrations and weight and the distance from the landfill at which the plot occurred were observed. Plots 2, 9 and Transect 1 Plot 8 were all areas that were easily accessible and just out of the public eye. These areas were also more representative of dump overflow; however, this is unlikely for Plot 9 and Transect 1 Plot 8 as they were not in the direct proximity of the landfill, but rather quite far away. These areas also contained wastes much more representative of being left behind by its previous owner – shoes, wheels, cabling, the lid of a laundry machine, an engine part, and food and drink related items. Plot 2, although it doesn't have the greatest weight of the area, definitely contained the most items. The area where the plot was located also seemed like an extension of the landfill – there was rusty material scattered around the area, ranging from rusty wiring to motorbike frames. In the area also a wide variety of trash was found, mostly heavier materials as opposed to soft plastics, further supporting the hypothesis that in the Left Parkietenbos the majority of the trash is soft plastics due to the wind directions.

5. Concluding remarks

The preliminary findings of this research provide clear insight into the current conditions of the study areas, especially highlighting the increasingly degraded state of the Left Parkietenbos. The pH-gradients observed indicate that the Left Parkietenbos truly has an extremely acidic substrate, unquestionably less preferable for the vegetation. Such acidic concentrations suggest that certain processes are affecting the area, and it is likely the landfill is, unfortunately, leaking certain chemical wastes. Interestingly though is that the Right Parkietenbos does not have the same acidic subtrate. This could be explained however as the Right Parkietenbos is predominantly an overwash basin and also is next to a less heavily used area of the landfill (currently the right side of the landfill is used for the burning of plant debris).

The solid waste findings suggest that improper waste disposal continues to play a large role in the health of the mangrove system of the Left Parkietenbos, as the vast majority of the waste found in the area is comprised of soft plastics, and most likely entered the area through wind transportation from the landfill, and being held by the mangroves. For the Spanish Lagoon and Right Parkietenbos it is less easy to claim a definitive origin of most waste collected. Whilst it is very clear that large amounts of trash collected were simply the result of illegal littering, a large amount of trash could also originate from the waterways, or have been transported by winds also.

Necessary though is increased awareness of the current situation, and the mentality of waste disposal methods and attitudes in Aruba should be altered, as it is clear that not enough of the local citizens and tourists are concerned enough with the damage such waste is causing.

Additionally, the Parkietenbos Landfill and Container Park should be closed, the area cleaned and decontaminated, and should a landfill still be necessary if Aruba is not 100% dedicated to the BioGas industry, then at least modern waste disposal methods should be applied. This involves the immediate removal of all open-air burning, and essentially means all materials that can be recycled, are separated and recycled, and only excess wastes are burned in a closed and contained fire, with special filtration systems that remove the vast majority of the chemicals released by the fire.

In answering the first question we can conclusively say that our preliminary findings provide evidence that shows that the Landfill and Container Park boundaries are not clear, nor are they maintained, due to the large volumes of waste escaping the system, the underground processes occurring creating a more acidic neighboring environment, and of course, the constant open-air burning heavily polluting the surrounding environment.

5.1 Research continuation

Further statistical analysis of our results will occur, and we will assess at least the following information; we will examine if there is a link between the pH-gradient and trash concentrations and its specific compositions recorded; and whether there is a relationship between the circumference data and the pH-gradient or the trash concentrations. In doing so, we are examining if there is evidence that suggests that either the pH-gradient of the trash concentrations are stunting tree growth and productivity. The productivity is measured through tree count.

5.2 Further Research

For further research we strongly advise conducting longitudinal studies including net primary productivity, collecting more extensive data on all sites, and to include more study areas of Aruba such as Isla di Oro, Mangle Halto and the barrier Reef as all of these areas have significant mangle growth, and could provide interesting information about the ecology of the island and how the local conditions affect the areas. Additionally, more specific research should be conducted to assess the leaching qualities of the Landfill and Container Park, to provide a better inventory of the leachate materials which could, in turn, help determine which substrate areas specifically are more damaged and altered, and which materials should receive extra attention during clean-up of the areas.

Acknowledgements

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