Landscape series 5

Housing and accommodation in recent decades in Aruba

Tile painting by Dan Jensen From: www.lago-colony.com

The Aruban landscape has undergone many changes in history. This paper is part of the landscape series:

"Spatial Developments in the Aruban Landscape: A multidisciplinary GIS-based approach derived from geologic, historic, economic and housing information"

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This paper is part of a series on the Aruban landscape. To bring perspective to current environmental threats and developments we provide, in this paper, based on information from the Census in 2010 (CBS, 2010)*, a detailed view on the spatial pattern of distribution of a number of housing characteristics that link to environmental sustainability and the wellbeing and health of local living conditions.*

Housing and accommodation in the past

Until the end of the 18th century[1], personnel of the Dutch West India Company (WIC) housed in Noord[2], near the Indian community that resided in the surroundings of Alto Vista, at Fontein (near the only natural freshwater well) and near 'Paarden Baai'[3] (due to its accessibility as a harbor).

With the construction of Fort Zoutman at the 'Paarden Baai' in 1797-1798, housing at the bay became more attractive. The WIC commanders already had taken position near the bay, in Hato and in Ponton. The name 'Paarden Baai' is reminiscent of the shipment activities at that time, when horses (Dutch: 'Paarden') were transshipped between Venezuela and Jamaica. After the first king, Prince Willem I of the family '*Oranje',* came to rule the 'United Kingdom of the Netherlands', the name of the small township at *Paarden Baai* was changed into *Oranjestad* in 1824 (Alofs & Romondt, 1997). Oranjestad grew to become the capital and center of trade activity in Aruba.

Today, most public offices, financial and legislative institutions and trading companies have their businesses in or near Oranjestad. Thanks to its central geographical location and proximity to the gold melting facilities in nearby Balashi, the township of St. Cruz prospered as well, but lost some of its prominence when the gold industry came to an end. San Nicolas already served the shipments activities from the phosphor industry in nearby Seroe Colorado, but when the Lago Oil Refinery opened its doors in 1929, San Nicolas became a bustling city. New construction for housing and accommodation closely followed this spatial pattern of economic opportunities and prosperity in the different regions (Derix, 2016d).

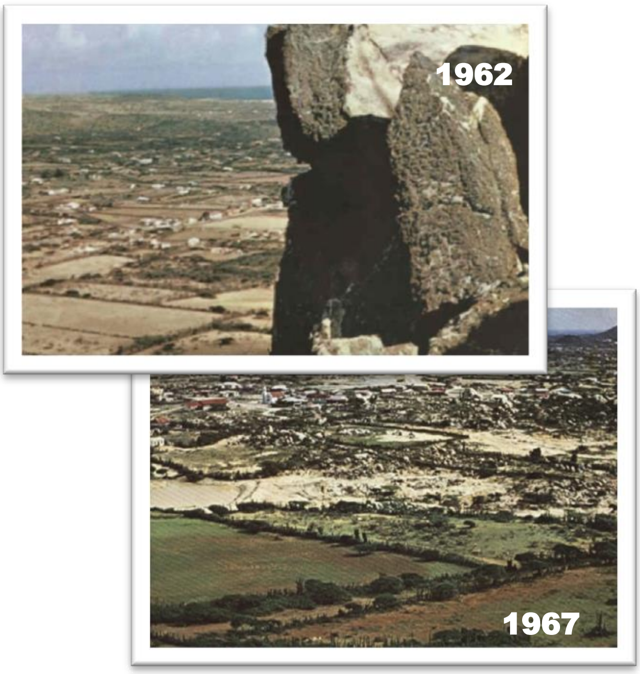
Built on the wind

Current housing units in Aruba may date as far back as to the beginning of last century and reflect the building styles of subsequent periods of external influences, economically as well as culturally. To get an idea of the different housing styles, the way of living, and the economic and political developments in Aruba over the last century we refer to the illustrative book by Bakker and Klooster (Bakker & Klooster, 2007) and the review by Alofs and Merkies (2006). The title of this section 'Built in the Wind' refers to the same title of the book by Bakker and Klooster, in reference to the typical way of construction of the former cunucu houses. We give a short impression.

At the turn of the 19th into the 20th century, at the time when the Werbata (Werbata, 1913) maps were made, houses were constructed from locally available materials. The Werbata map accounts three different types of houses. Walls were made from wood, from twined branches, plastered with mud and clay, or from blocks of granite and quartz diorite stone. The stone houses typically had thick outer walls and small rooms, but were cool and well ventilated. The tile painting by Dan Jensen (see the photograph on the front cover) is illustrative of the shape of the cunucu houses at the time. The bedrooms were commonly facing the windward side of the house. In a corner inside the house there was a water cistern that held fresh and cool rainwater. The kitchen was at the side of the house off the wind, to prevent the instant spread of fire from an accidental flare. The entrance was often to the west, also off the wind to prevent dust from getting inside. The oven was built against the kitchen wall and originally only accessible from the outside. Only after the outer walls were made from stone, it was safe enough to have the oven accessible from the inside.

With the growing population, the arable land surrounding Oranjestad was more and more developed for agriculture. Attempts to cultivate on the lower grounds near Santa Cruz proved to be successful and the initiative was soon followed by the exploitation of soils in the outer regions (Alofs, pers. comm.). Terrains were fenced by loose stone walls ('transhi') or built with columnar cacti tranches ('trankera') to keep the free roaming herbivores outside (or corralled). Stone walls were also used to prevent the land from erosion. Original mansions and row-houses were typically influenced by Dutch tradition, but with the arrival of the oil industry, American architecture was introduced. Interestingly, many houses in San Nicolas were built in the typical Caribbean style architecture in an effort to comfort immigrant Caribbean workers (Alofs & Merkies, 2006)

Photo series 1: An impression of the open agriculture landscape in 1962 (A.J. Casali, Lago calendar) and 1967 (Lago calendar). Both photographs were made from the top of the Hooiberg, and were oriented towards the Northeast. Source: www.lagocolony.com



[1] L. Alofs, pers. communication, 2016.

[2] The settlement Noord was established in 1774 (Alofs & Romondt, 1997)

[3] *Paarden Baai* translates in English as 'Horse Bay'

The photos below and on the previous page illustrate the open wide panoramas in the landscape in 1948, 1962, and in 1967. In 1948, already some of the fields were left abandoned, but the countryside was still dominated by Aloe fields and agriculture (Photo below). In the fifties, Voous (1955) and Stoffers (1956) described the landscape as generally very barren and dry and without much vegetation. Wild vegetation was merely along the dry-river beddings and in the region that roughly depicts Parke Arikok today. Agricultural terrains were largely abandoned and overgrown already (Stoffers, 1956).

The countryside in the sixties (see photos) was also still reminiscent of the open agricultural panoramas, dominated by the cacti, tree and scrub borders. The apparent bare landscape was without much vegetation, probably due to prolonged periods of relative drought. This and the decennia before were the times when many of the decision makers of today grew up. The landscape called '*Mondi'* was overgrown with cacti, herbs and shrubs but had the accounts of the beauty and hardship of the former cunucu landscape. With the new focus on economic prosperity and financial growth, there was little respect for nature. The situation was soon to change even more as the population numbers increased and the countryside was turned into housing projects.

We added to the image in figure 1 some color to stress the contrast between the extent of the dominant agricultural countryside in 1948, somewhat at a distance from Oranjestad, the large (former) terrains with Aloe cultivation in the immediate surroundings of Oranjestad, and the more densely inhabited center of Oranjestad.

It is interesting to analyze and reveal the patterns that accompany the strong increase in construction from last decennia (Derix, 2016d). Variation and changes in household characteristics, such as the size of the living space, type of building material, and the presence of air conditioning units, link to ambitions of a more sustainable and environmentally friendly environment.

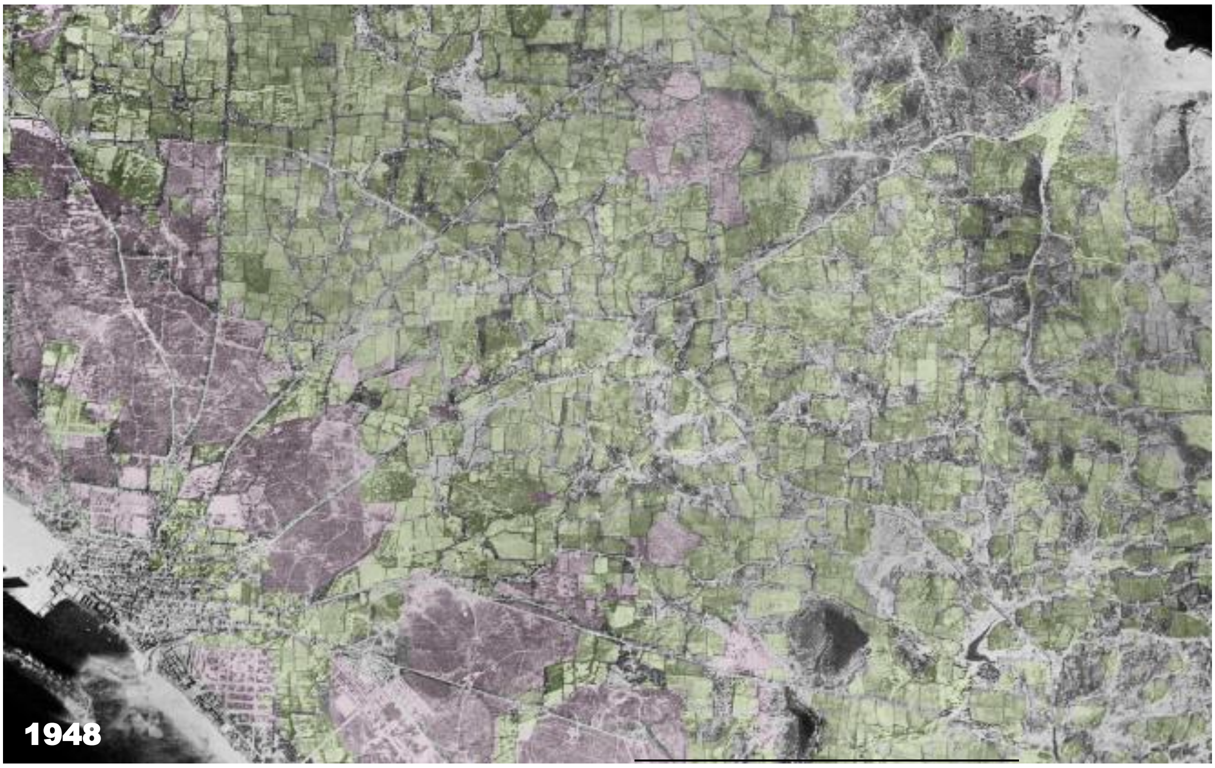
Housing characteristics

First, we describe the spatial variation in housing characteristics in Aruba at the time of the Census in 2010. Based on the information from the housing census we have analyzed the individual housing characteristics and the different building materials to the periods of construction. Our aim is to reveal trends in the way we use and shape our local environment.

The size of the built-up area, the use of different building materials, or the type of rooftop material may show an association with household budget, but may also depend on time specific common practices or local availability of materials. Some materials are more expensive than others. Also, some regions are more desirable than others (Derix, 2016d). Regional variation in housing characteristics may reflect differences in the privilege to build in certain areas and can have a different effect on the facet of the landscape.

The technique to measure and analyze the dependency among characteristics in a geographic space is called 'spatial autocorrelation statistics' and takes into account the co-variation of properties with each other and with space. Such spatial analysis includes a variety of techniques, and is still in development[4].

Figure 1 Aerial photo from 1948 (KLM Aerocarto map)
We colored the b/w photograph partly in purple and green to point out where in 1911 the terrains with Aloe cultivation and mixed agriculture, respectively are situated. The information is based on information from the Werbata map (Werbata, 1913).



[4] *www.**spatialanalysis**online.com*

Square gridded areas with on average large household *plot sizes* (grid cells colored in red) show no concentration in specific regions, albeit that large *plots* appear to occur more likely at the border of uninhabited space (where there are no grid cells).

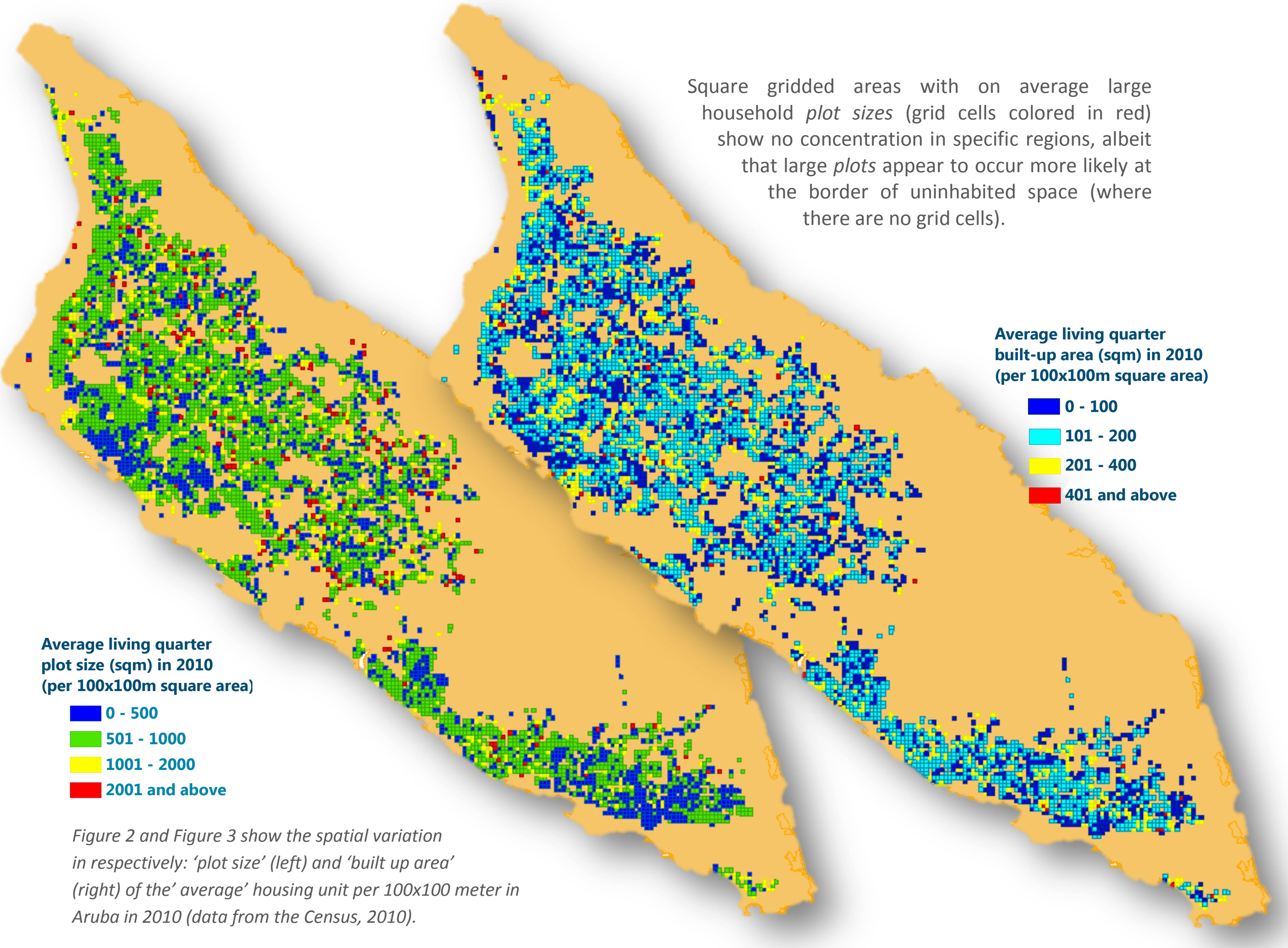


Figure 2 and Figure 3 show the spatial variation in respectively: 'plot size' (left) and 'built up area' (right) of the' average' housing unit per 100x100 meter in Aruba in 2010 (data from the Census, 2010).

A simpler regression analysis to analyze the spatial distribution of housing characteristics may prove inadequate as we have no means to control for the fact that, consequential to the typicality of spatial characteristics, "near features are more likely to be similar to each other than to distant features".

For the purpose of our study, we chose to simply describe the variables in a two- or three-dimensional space and refer to them as a tentative induction of underlying patterns. Therefore, we cannot be conclusive about the causal relation between the observed phenomena, yet our findings suffice to show trends and the corresponding spatial associations.

Smaller plots and living quarters

First, we analyzed the distribution of plot sizes and built up areas at a spatial resolution of 100x100 meter square areas (figure 2 and 3). We used the average as a parameter because our focus is on a comparison of the surface areas and less on the frequencies of occurrence.

Visually, we cannot discern any spatial pattern other than the expected local concentrations of similar sized small *building plots* and *built up areas* in the city center in Oranjestad and San Nicolas and in a number of areas that concern residential development projects.

Interestingly, in *plot size* as well as in *built-up area* an equal spread and variation exists across all the inhabited space.

Similarly, there is no specific pattern recognized in the spatial distribution of *large built-up spaces*, aside from some concentration in neighborhoods like *Malmok*, *Ponton*, Mon *Plaisir, Wayaca* and *Seroe Colorado*.

Figure 4 Relationship between period of construction of the living quarter, plot size, and built up area (Census 2010).
Note: The last decennium 2000-2010 is split into two categories 2000-2004 and 2005-september in 2010.

The graph in figure 4 shows a categorization of *plot size* and *built up space* in 2010 by 'period of construction'. The graph reveals that from the 1960's onwards there is little or no apparent change in *plot size* (the median value per grid cell is about 600 m^2 per housing unit). We do observe a peak during the 1980's as the median plot size over that time period is somewhat larger, about 650 m^2.

The median plot size of older housings built during the 1950's, is clearly smallest (500 m^2). We find many small plots in the direct surroundings of Oranjestad and San Nicolas (Figure 2) in areas with housing projects from the 50s (see also an earlier paper in this series (Derix, 2016d)). In regard to the size of the *built-up area*, a trend is noticeable towards smaller built-up areas from the 80s onwards. The smaller plot size concurs with the rapid growth of the population, the increase in costs of construction, and the increased demand for new housing (Derix, 2016d).

Less rooms and more floors

Based on information about the period of construction, and a number of housing characteristics, such as the amount and size of living spaces inside the house, the number of floors and the household income, we can show how we managed to attain a higher standard of living over the last fifty years.

The analyses (Figure 5) reveals a shift towards *fewer rooms* per housing unit from the fifties onwards. A '*room*' is defined to include *all bedrooms, the dining room and/or living room, the kitchen, and, when present, also the enclosed patio/veranda/porch.*

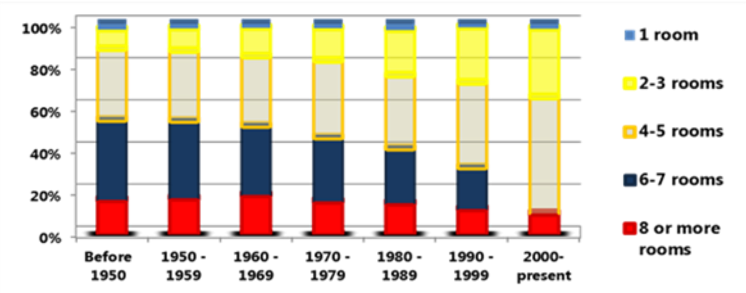


Figure 5 Percentagewise distribution of number of rooms per living quarter per period of construction (Census, 2010).

Thus, older housings generally have more rooms. In 38.6% of the housings that still exist from the fifties we observe 6-7 rooms and in 15.8% of cases there are even more than 8 rooms, whereas only about 9.4% of these housing units have 2-3 rooms. The number of rooms per housing unit decreased up to an average of 4 to 5 or even less in the most recently constructed housing units. New housing units built over the last decade have on average in 18.3% of cases 6-7 rooms, in 44.4% of cases 4-5 rooms, and in 26.2% of cases only 2-3 rooms.

Without further illustration, we like to note that at the spatial resolution of administrative (GAC) zones (N= 48) little or no geographical variation existed with regard to the *average number of household members* and *number of bedrooms per housing unit.* The ratio of *household members per bedroom* provides a good insight in the level of crowdedness in a given area. Across all zones, we observe in 26% of housing units more bedrooms than there are actually household members, in 54% of cases we count an average of 1-2 persons per bedroom, but in 16% we count 2-3 persons per available bedroom, and in 4% of cases there are even more than three (3) persons counted per bedroom. In only a few zones these numbers differ from the average, i.e. at the one end of the extreme, in *Seroe Colorado,* where we observe that the majority of housing units (58%) have more than one *bedroom* per household member available, and, at the other end of the extreme, is *Madiki* and *Rancho,* where we observe in 10% of housing units an average of more than three (3) household members per available bedroom.

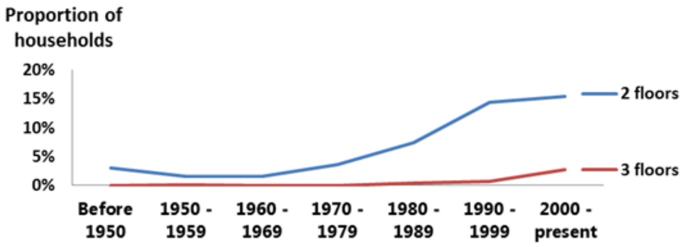


Figure 6 Proportion of housing units that have multiple floors per period of construction (Census 2010).
Note: In order to emphasize the temporal changes we represented subsequent period intervals as a line diagram.

Another striking trend is that more recently constructed housing units, in the last decades, have more often *multiple floors* with living quarters compared to houses that are built before (Figure 6). Housing units that were constructed after 2000, have in 15.4% of cases two (2) floors and in 2.7% of cases even three (3) floors. Houses built before 1950 have more than one single floor only in 3.0% of cases.

Income and the choice of housing materials

The next step in our analyses was to determine the relationship between building characteristics, such as the size of the plot and built-up area, the presence of fencing, the type of construction material, and the total household income[5].

Old cunucu houses had thick walls and are known for a mild climate inside. The thick walls not only had a high thermal mass, but were built with natural stone and cemented together by a mixture of mud and sands. These natural materials allowed evaporative cooling of the house interior. Cooling by ventilation was neither a problem since the old cunucu houses were generally well positioned in the wind.
The technique to construct thick outer walls is not in use anymore because of the elaborate work and costs that come with it. The use of cement blocks requires less maintenance and they are easy to handle, offer more flexibility for construction and are weatherproof, robust, and durable. The disadvantage is that to lower the costs of building, new-owners generally prefer single-stoned walls. The result is that with the heat buildup at the sunny side of the house façade the thermal capacity of the cement blocks is insufficient to prevent heat transfer inside. Therefore, to lower the heat buildup from the outer envelope of the house and improve the interior climate conditions, air-conditioning systems are installed nowadays.

[5] The total household income is defined in broad income classes and includes the earnings from all household members, based on the information that was provided by the household members during the household Census in 2010.

Shading from trees and other vegetation is considered an alternative to prevent the heat buildup from sun radiation on the outer walls and also increase the micro-climate conditions in the garden surroundings by evaporative cooling (Akbari, 2002). Vegetation too close to the house, however, is often undesired or impossible. Therefore one may consider reflective coatings or other insulation techniques, which exist for rooftops[6], to prevent heat absorption of the outer envelope of the house and protect against radiative heat emission inside.

Concerns about the costs, quality and energy efficiency of materials and techniques used in construction apply for the complete housing envelope, including the roofing material that is used. Roof tiles generally provide a somewhat better thermal performance and protection against the heat radiation inside, than shingles and metal sheets (Akbari, 2008). The commonly used technique, for instance when metal plates are used as rooftop material, is to construct a lowered ceiling. The large air-filled heat storage capacity above the ceiling protects against heat radiation directly inside the living space. We lack data about its occurrence, but it is safe to say that many of the houses in Aruba, that generally have only a single floor, do have a lowered ceiling, albeit that it is fashionable nowadays to have the lowered ceiling removed.

The analysis above (Figure 7) reveals a positive relationship between the *size of the plot* or *built-up surface area* and the *total household income.*
In lower household income situations (below Afl. 1,550 per month) we observe a flattening of the curve as the median built-up area remains at about the same level (ranges between 70-84 m^2). The results show that living space can be considered a scarce good and those who can afford it are privileged to attain more of it.
We chose to compare household characteristics with the total (categorized) household income and not to take into account the number of household members that will certainly have an effect on the height of the household income. To minimize the influence caused by the incidental presence of very large plots[7] or large size of the household, we used the median value instead of the average.

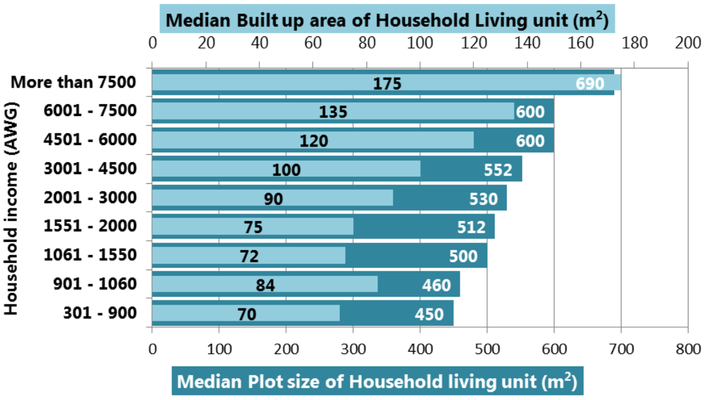


Figure 7 The graph presents the relationship between household income, plot size, and built-up area of the living quarter, based on the data from the Census in 2010.

Another housing unit characteristic that may relate to the privilege of a higher living standard is the level of fencing of the home compound. The 2010 Census data show that, overall, more than half of all households have fenced the land surrounding their living quarter completely. Figure 8 shows that the proportion of fencing does increase with higher total household income.

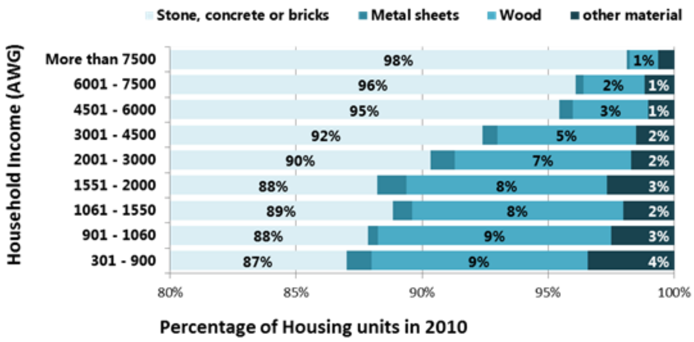


Figure 8 Relationship between total monthly household income and level of fencing around the living quarter.

In the household income classes below Afl 4,500 per month, the proportion of housing units that are completely fenced, partially fenced, or have no fence at all, remains about the same, irrespective of total household income.
In these (low and medium) income classes, in about 19%-21% of cases the terrain is partially fenced, while 22%-25% of housing units had no fence at all. The majority of housing units in this income range, however, (55%-58%) have their plot completely fenced. In higher income classes there is a trend towards complete fencing.

[6] When the sun's radiation hits the roof it strongly depends on the roof material properties and construction design of the roof envelop to determine how much heat will be transferred into the living spaces below. Important properties are solar reflectance (the fraction of the sun's radiation that is immediately reflected back into the sky), absorption (the fraction that is absorbed by the roof material), conductivity (the ability to transfer some of the absorbed heat away from the source) and the thermal emittance (the ability to radiate some of the absorbed heat). These properties, however, are no constants, but vary with varying climatic circumstances and aging. The essence of a cool roof (and walls) is to minimize solar heat buildup and heat radiation inside and to maximize reflectance. In addition, alternative approaches may involve additional insulation or a different design of the outer envelope that allows for ventilation (i.e. elevated batters) or evaporative cooling of the air flow/convection on top of the roof surface.

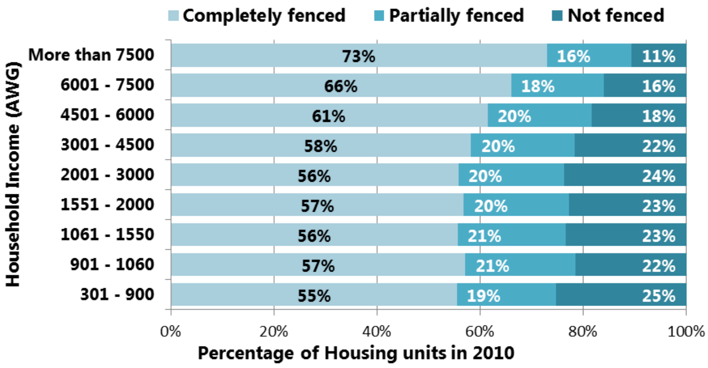
[7] Figure 3 and 4 have shown that there is considerable spatial variation in built-up area and plot size as well as a concentration of similar sized (parceled) plots predominantly in the centers of Oranjestad and of San Nicolaas and in the local housing development projects. Large plot sizes do still exist, however, and may be in family possession for a long time. To prevent that incidentally exceptionally large plots (or built-up areas) bias the outcome, we chose to present median built-up area and median plot size per category instead of the average.

In the income class ‘above Afl 7,500’, the trend is towards complete fencing, i.e. 73% of housing units have their plot fully fenced, 16% have partial fencing and only 11% have no fence at all.
The results show that fencing is less considered a luxury good and is present in over half of all households, irrespective of their income. The results also suggest that still, for those who may be able to afford it (observable in the household income classes above Afl. 4,500), there is a tendency to have their house completely fenced dependent on household income.
For the majority of living quarters in Aruba the prevalent material to construct the living quarter is by concrete-blocks (in Papiamento: *Blokki)* or stone (range varies from 87% of households in the lowest income class to 98% in the highest income range). Still, we may observe a positive association between the use of concrete-blocks and household income as some housing in the lower income classes use different materials (Figure 9). There is a low tendency in the lower income households to build the outer walls of the housing unit from wood.

These results need some clarification. In 2010, about 80% of households lived in a house, 17% lived in an apartment and respectively 2% and 1% lived in a remodeled (metal) sea freight container or in a shack. On average, in 2010, about 93% of these housing units were built from stone, 5% from wood, and respectively 1% and 2% of housing units were built from metal or another type of material. Only very few (often historic) wooden houses still exist today. The graph in figure 9 only shows part of the full range of used construction materials (x-axis ranges from 80-100%).

Concrete blocks thus, are the norm where the construction of outer walls is concerned. From discussions with local constructers we understand that most houses have no specific outer wall insulation, and there is also little knowledge about alternative construction designs or use of alternative materials/techniques to minimize heat transfer to the inside of the house. Often, the outer walls are sun-drenched. Concrete blocks do have a high thermal mass that is perfect for storing heat, but as most houses in Aruba are built from single layer ‘blokki’ (concrete blocks) the heat buildup during the day may become so intense that heat is radiated inside.

Figure 9 Relationship between household income and most prevalent material for the outer walls of the living quarter.
Note: the range on the lower axis is between 80%-100%. Thus as well in the lowest income class 87% of households use stone, concrete or bricks as major construction material.



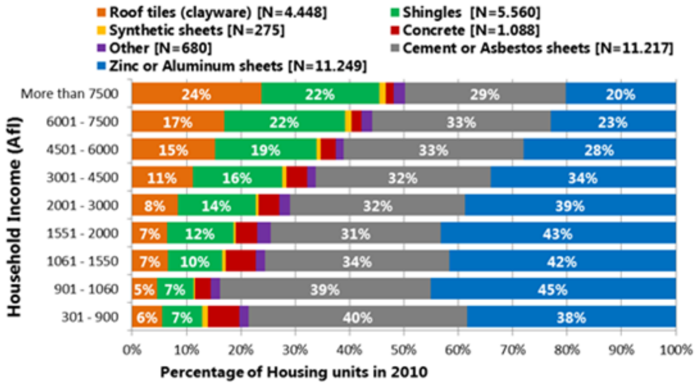


Figure 10 Relationship between household income and roofing material

In Aruba roof tiles and shingles are more present in housing units inhabited by households with a relatively higher income (Figure 10)[8]. Respectively, 24% and 22% of households with an income above Afl 7,500 per month live in a housing unit with a rooftop built from clayware tiles and shingles, whereas these percentages are as low as 6% and 7% for household with a gross income in the category Afl 300 - 900 per month. In the lower incomes, we find more often sheets of corrugated cement or asbestos plates, or zinc or aluminum sheets (up to respectively 40% and 38% of housing units). The vast majority of roof tops today are, however, covered with metal- or cement/asbestos sheets. In 2010, 4,448 living quarters used ceramic tiles as primary rooftop material against 5,560 that used shingles, 11,249 that used metal sheets and 11,217 that used cement or asbestos sheets.

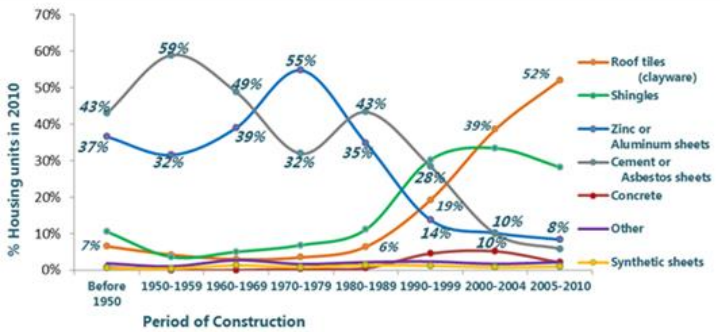


Figure 11 Distribution of type of rooftop material and period of construction of housing unit (Census 2010).

Not unexpected, we find a relationship between the presence of roofing material and the period of construction (Figure 11). Currently, the predominantly used type of rooftop material for new construction is roof tiles. We observe a shift in the material most often used for roofing when we compare the housing units from different periods of construction in 2010. During the 50s, a majority of houses were built with asbestos or cement roofing (in 59% of living quarters).

[8] A positive or negative association between the variables household income and type of construction material explains the relationship and relevance of both housing characteristics with each other, but does not necessarily indicate a causal relationship.

Interestingly, again, during the 80s, sheets of asbestos/cement were used most frequently. We believe, however, that the two peaks in the use of cement/asbestos plates over time are a misleading consequence of the fact that a rather broad definition was used during the Census in 2010.

During the Census in 2010, the two types of rooftop materials, asbestos and cement sheets, were combined namely into a single category given that it would be impossible for the surveyors in the field to distinguish between the two. The second peak, during the 80s, may however be dominated by cement-sheets only because at the time information about the health risks to use asbestos was already well available. So, the use of asbestos during the 80s is less likely (UvAWeb, 2012).

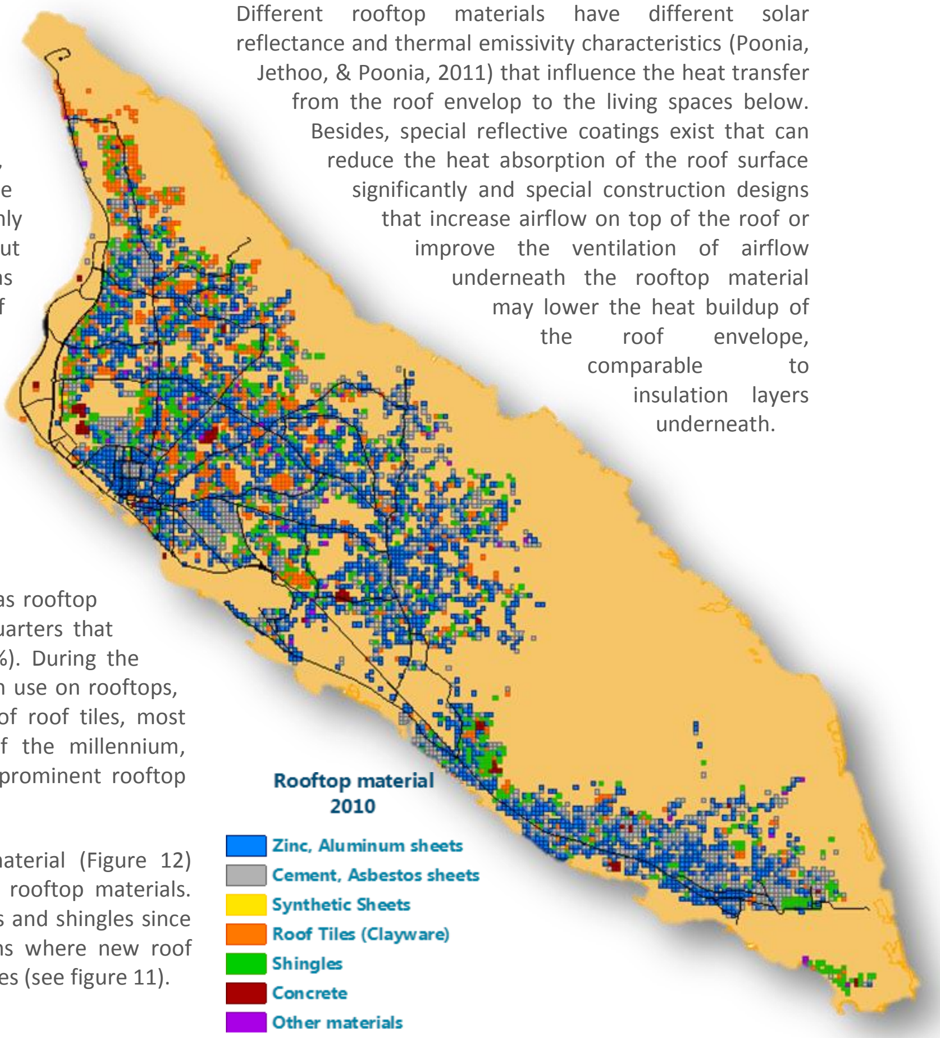


Figure 12 Spatial representation of type of rooftop material (Census 2010) based on the most prevalent rooftop material per 100x100 meter grid square areas. Source: Census, 2010.

The use of zinc and aluminum sheets as rooftop material is most prevalent in living quarters that were constructed during the 70s (55%). During the 90s, shingles were the main material in use on rooftops, but soon thereafter we see the use of roof tiles, most often from clayware. At the turn of the millennium, clayware roof tiles became the most prominent rooftop material in new house construction.

The spatial distribution of rooftop material (Figure 12) clearly reveals aggregations of similar rooftop materials. The increase of the use of ceramic tiles and shingles since the 90s elegantly reveals the locations where new roof construction took place in recent decades (see figure 11).

More air conditioning

Air-conditioning energy savings have become a topic in recent debate on how construction can help to become more energy-efficient, in particular in hot and dry climate zones[9]. Artificial cooling can be reduced considerably with roofing materials of higher solar reflectance and thermal emittance properties (Akbari, 2008), or, more generally, with a rooftop design that specifically allows for less heat transmission between the roofing envelop and the living space (Poonia, Jethoo, & Poonia, 2011).

To be exact, absorbed solar heat partly radiates inside from the rooftop and heats the air in the space below. When a lowered synthetic ceiling is placed beneath the rooftop, the space in between the rooftop and the ceiling acts like a buffer zone and keeps most (but not all) of the radiated heat during the day from entering directly into the living spaces below. This air pocket however does retain its heat also into the night, in particular when there is insufficient air flow and ventilation (which is often the case). As a result, at night, when the outside temperature drops, an AC in the bedroom needs to cool harder because the warm air pocket above the ceiling still transfers heat into the living space below. A brief introduction to the subject of cool roofs is given by (EPA, 2015)[10].

Different rooftop materials have different solar reflectance and thermal emissivity characteristics (Poonia, Jethoo, & Poonia, 2011) that influence the heat transfer from the roof envelop to the living spaces below. Besides, special reflective coatings exist that can reduce the heat absorption of the roof surface significantly and special construction designs that increase airflow on top of the roof or improve the ventilation of airflow underneath the rooftop material may lower the heat buildup of the roof envelope, comparable to insulation layers underneath.

In Aruba, many rooftops have corrugated metal sheets from zinc or aluminum or asbestos/cement-based sheets fixed to a wooden skeleton with often no insolating roofing panels underneath. This type of construction was affordable and became common practice for building houses during the 70s and 80s (see figure 11). Underneath the open frame was a lowered ceiling that protects the living space against intense heat buildup during the day. Temperatures in the space above the ceiling can rise to the extreme, which explains the need for ventilation.

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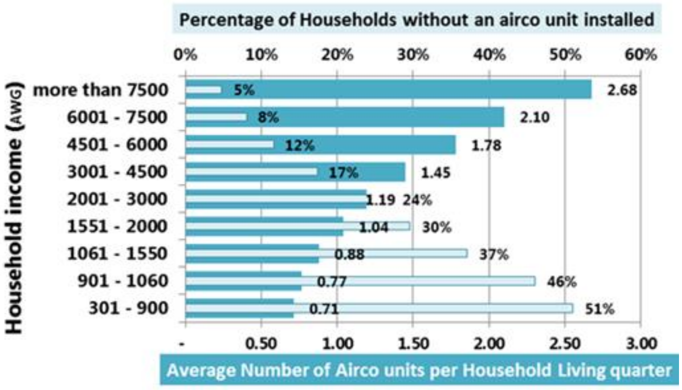
[9] www.coolroofs.org

[10] www2.epa.gov/heat-islands/reducing-urban-heat-islands-compendium-strategies

Figure 13 Relationship between household income, average number of air conditioning units per household, and proportion of living quarters that have no working AC units at all (Census in 2010).



These types of dwellings are mostly well ventilated. However, new house constructions use ceramic tiles or shingles on top of closed wooden panels, and such houses are easier to insulate than those with rooftops of corrugated sheets on a wooden skeleton.

As a result, modern households frequently use the option to have their living area completely closed to the outside and invest in air-conditioned cooling (pers. comm. with local contractors) improving their comfort but also raising the demand for electricity during the day.

In order to create a more sustainable energy-efficient environment it is worthwhile to evaluate the relation between construction and design characteristics of *residential* housing units and the presence of installed (and working) AC-units. Figure 14 and 15 give an overview of the abundance of household air conditioning systems in Aruba in 2010.

The spatial distribution of the total number of air conditioning systems per 100x100 meter area (Figure 13) follows closely the spatial distribution of number of households, i.e. most air conditioning systems are found in and around the populated areas, in Oranjestad and the surrounding areas, in Noord, Bubali, and in Pos Chiquito and in San Nicolas.

However, if we correct these figures for number of housing units, the distribution reveals a different pattern (Figure 14). In some areas residents own an above average number of air-conditioning units. Areas such as Bubali, Klip/Mon Plaisir, Wayaca, Ponton, Palm Beach, Bakval, and Salina Cerca in Noord, have a relatively high prevalent number of AC units (above 2.5 AC units per household). In some of these neighborhoods the most frequent number of AC units is as high as 5 per housing unit. Figure 14 also shows that, in the center and direct surroundings of Oranjestad and more to the south, in the region San Nicolas and surroundings, we observe the opposite, the most prevalent number of AC units per living quarter is noticeably low (often less than 1.0 AC unit per household)[11].

A total absence of air conditioning systems occurs in 20% of cases in 2010 (Table 1), i.e. in one of every five households.

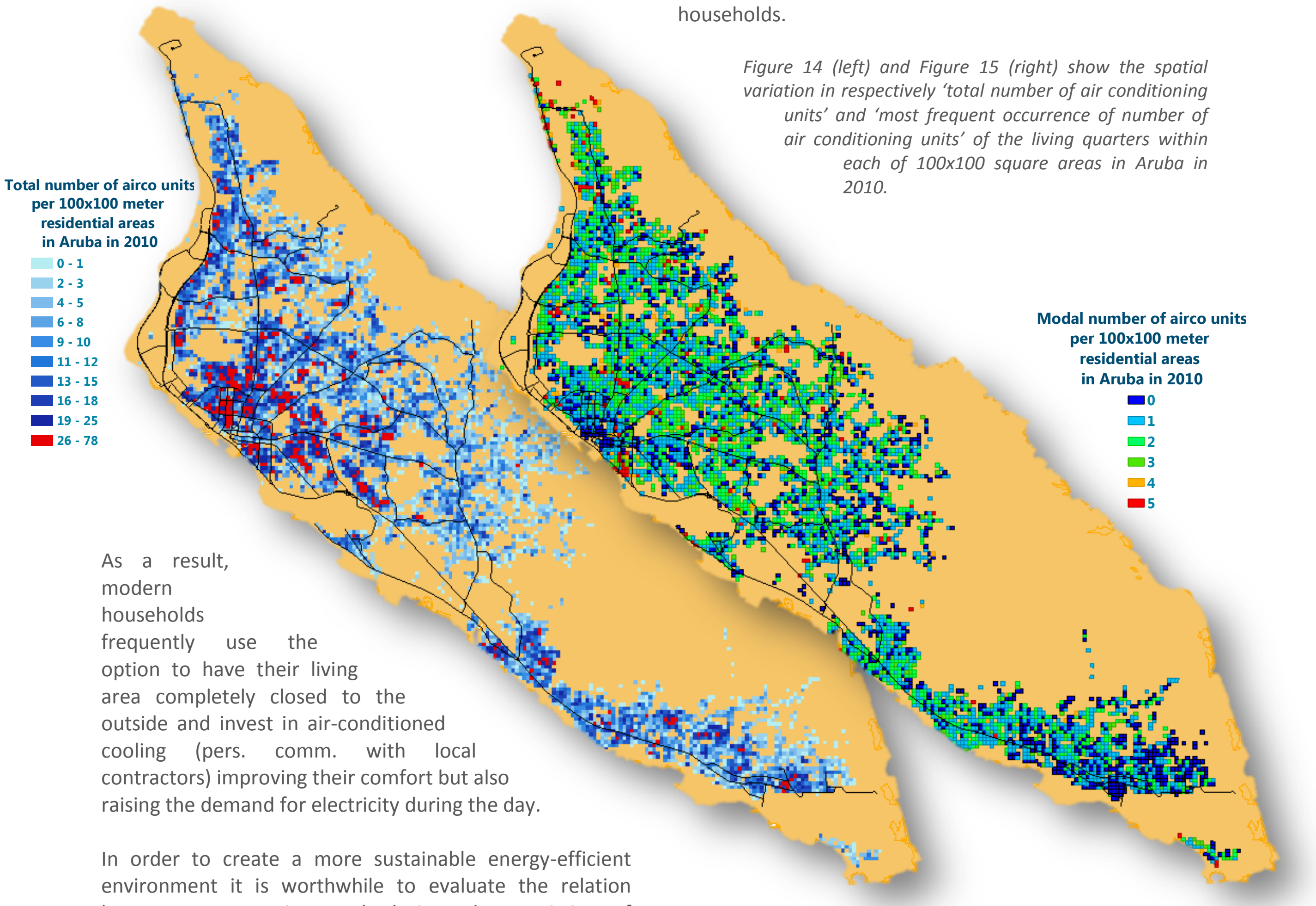


Figure 14 (left) and Figure 15 (right) show the spatial variation in respectively 'total number of air conditioning units' and 'most frequent occurrence of number of air conditioning units' of the living quarters within each of 100x100 square areas in Aruba in 2010.

[11] In the Census in 2010 and earlier Censuses, the question refers to the number of functioning AC units. Unfortunately, there was no option to ask for type of AC unit or BTU usage. In some cases, households may use a central air-conditioning system.

AC units/ HH	0	1	2	3	4	≥ 5	Total
%Households (HH)	20%	33%	25%	14%	5%	3%	100%

Table 1 Distribution of Households over number of AC units per household (source: Census 2010).

These households are spread all over the island albeit apparently somewhat more prevalent in the rural areas east of Santa Cruz and east of Noord towards the coast (Alto Vista and Calbas) and in and around Oranjestad and the complete surroundings of San Nicolas. Some of these locations will be more open and windy and may require less cooling, but in the majority of these cases, the housing units are situated in the city center or in more populated areas. Other reasons, such as low income may apply why occupants would not be able to afford an AC unit.

The importance of household income in regards to the ownership of air conditioning units is explained in Figure 15 in more detail. The variation in number of functioning air conditioning units per households ranges from 0.71 in the low income class (Afl. 300-900 per month) up to an average of 2.68 AC units in the high income class (above Afl. 7,500). The percentage of households that possess no air condition unit at all is highest (51%) in the lowest income class (Afl. 300-900) and lowest (5%) in the highest income class (above Afl. 7,500 per month).

Since the space that is most likely to be cooled at night is the sleeping area, we detailed the relationship between type of rooftop, number of working AC units and number of bedrooms per living quarter (Figure 16). Beyond 4 bedrooms per housing unit we have insufficient data for a comparative analysis.

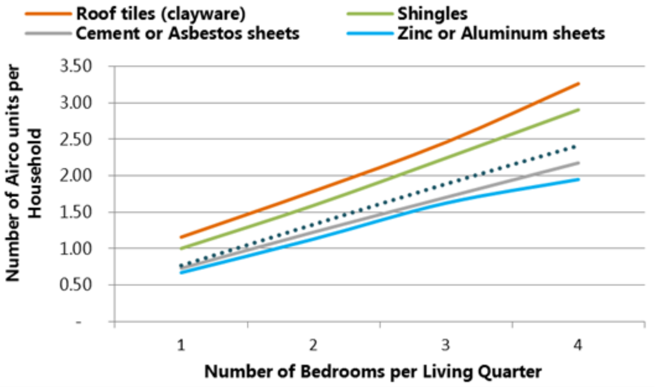


Figure 16 Average number of working air conditioning units installed per type of rooftop material and number of bedrooms in the housing unit in 2010. The dotted line represents the average irrespective of type of rooftop material.

On average, despite the positive relationship that more bedrooms relate to more AC units, the number of air conditioning units is almost always less than the number of bedrooms, irrespective of the type of rooftop material. Overall, however, living quarters with ceramic roof tiles have on average more AC units per bedroom than living quarters with shingles. Living quarters with shingles have in turn, on average more AC units than living quarters with a rooftop of asbestos or cement plates. The lowest number of AC units is observed when the rooftop is with zinc or aluminum sheets (Figure 16).

In figure 17 we present information about the relative distribution of living quarters with a given type of rooftop material per number of installed AC units.

We observe a positive association between the amount of working AC units and the presence of *ceramic roof tiles* and *shingles* and a negative association between the amount of working AC units and the presence of *zinc or aluminum sheets* or *asbestos or cement-based sheets*.

Housing units with 5 or more AC units installed have in 32% of cases a rooftop with ceramic tiles and in 24% of cases one with shingles, but in housing units with only one single AC unit installed, these figures are, respectively, 9% and 15%. In contrast, in housings with 5 or more AC units installed 18% are with zinc/aluminum sheets as rooftop material, and 21% have asbestos/cement-based sheets, whereas these proportions are as high as 38% and 32% in situations when there is only one single AC unit installed. In households that have no working AC unit at all, the rooftop material is even more often with '*zinc or aluminum*' and '*cement or asbestos*' sheets (respectively 44% and 36%).

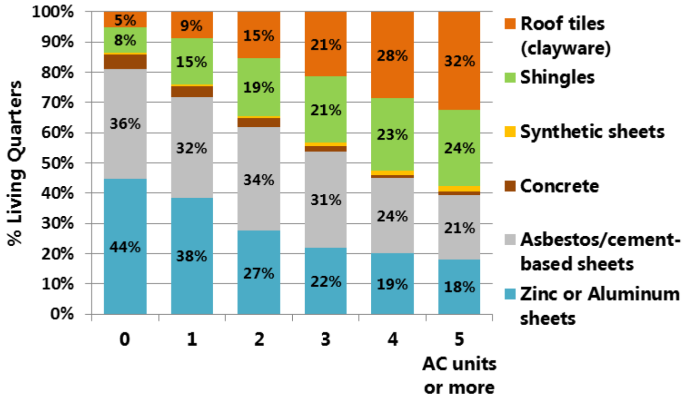


Figure 17 Proportion of living quarters per number of air conditioning units installed for type of rooftop material (Census 2010).

It is, however, difficult to interpret our findings in terms of necessity to install more or less AC units for the mentioned rooftops. Firstly, not only the type of roof materials, but also the type of roof designs, i.e. the complete roof envelope and house construction, determines the amount of heat transfer into the living space. Unfortunately, the Census did not provide information about the design details of the roofing envelop in Aruban housing units, so we have insufficient data to analyze this aspect.

Furthermore, the information presented in figure 10 shows a strong association between the use of ceramic tiles or shingles and higher income households. A similar positive relationship is shown in figure 15 and exists between number of AC units installed and household income. Understandably, higher income households can afford not only more AC units, but can afford also a more durable and attractive roof type with adequate insulation that will also allow a more energy-efficient use of the AC units. Nevertheless, in Aruba, most households still have rooftops from zinc/aluminum sheets or asbestos/cement-based sheets and have relatively fewer AC units.

Towards a more sustainable living

In a previous study (Derix, 2016d) on the suburbanization of the Aruban countryside we highlighted the increase in housing units in particular during recent decades and the spread of buildings across the island in association with spatial economic developments. Here, we elucidate some of the trends that can be recognized in building construction and housing characteristics.

The trend in housing units in Aruba appears to shift towards a smaller built-up surface area, fewer rooms and more than a single floor level. We observe a range in housing characteristics that vary with total household income. Higher income households tend to have a larger built-up space, completely fenced terrains and more frequently use stone, concrete or bricks for the construction of the outer walls as well as ceramic tiles or shingles as rooftop material.

These trends reveal a direction towards smaller living spaces in a denser built-up environment. As this trend is likely to persist, this may have consequences not only for a loss in remaining landscape but also for the 'suburban' micro-climate in and around our living spaces. Despite the fact that many of the housing units in the dense city center of Oranjestad and San Nicolas are relatively small and often without AC unit, the total number of residential AC units in these areas still is very high. Given the presence of many businesses that use AC units during the day, it becomes obvious that local micro-climate conditions will spiral towards a less favorable ambience like predicted by the '*heat island'* [12] effect ((Bharat, 2009) (EPA, 2014) (Golden, 2004)). We lack specific information about whether a heat island effect exists in Aruba, but it is safe to assume that with the increase in construction and suburbanization (under the tropical climate regime), there will be higher local micro-climate temperatures, due to the absence of the cooling effect from winds, and, shade or evaporation from vegetation.

Consequently, this suggests a reinforcing feedback loop towards an increased energy-demand for air-conditioned cooling.

From an environmental point of view and in terms of improving energy-efficiency[13] most (AC-related) gain can be made with improvements in the thermal characteristics of the total roofing envelop of housing units with zinc/aluminum or asbestos/cement-based sheets, simply, because these types of roofs are the most prevalent in the urban as well as in the suburban and rural areas (despite a current trend towards the use of ceramic roofing).

However, the households involved probably cannot afford costly structural roofing improvements. Recent studies, such as by Alvarado & Martınez (Alvarado & Martınez, 2008) and Miller et al. (2012) focus on alternative cost-effective means to improve the thermal properties of the roofing envelope.
Because of the high material costs involved, it is relevant to search for and support alternative approaches on how to cool the inside home environment in particular in lower income households that lack the means to invest in energy-efficient rooftop constructions.

Energy-efficient construction standards and designs as well as projects that attempt the greening of the suburban environment already have become common practice in several countries abroad[14]. Some approaches deserve wide recognition, such as more sustainable spatial urban planning with shady vegetation to alter the local ambient circumstances (and increase evaporative cooling) and the use of reflective coatings, insulation or the placement of additional roof or wall panels that create shadow on the sunlit parts of the outer house envelope. Also, alterations that improve air ventilation along the inner or even outer roof surface will minimize the level of heat buildup and improve living conditions as well as reduce costs for artificial cooling.

In an effort to become more sustainable it is relevant to gain insight in the distribution of energy-consuming living standards. In this paper, we analyzed some trends in housing characteristics in Aruba to illustrate the changes that have taken place in how we live and how we change our direct surroundings. We linked information about construction and housing characteristics as well as the use of air-conditioning systems in order to give insight in what privileges we attempt to pursue on the road to sustainability and energy-efficiency.

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[12] From EPA: Referenced by *Bharat* (2009) 'Heat islands form as vegetation is replaced by asphalt and concrete for roads, buildings, and other structures necessary to accommodate growing populations. These surfaces absorb – rather than reflect - the sun's heat, causing surface temperatures and overall ambient temperatures to rise'.

[13] *Only very recently energy-efficiency is put back high on the agenda, not because there is a lack in energy but because the global climate is turning erratic.*

[14] http://www.epa.gov/greenbuilding/standards

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